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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Return and Volatility Connectedness in Electronic Warehouse Receipt Market of Turkey

Türkiye'nin Elektronik Ürün Senedi Piyasasında Getiri ve Volatilite Bağlantılılığı

Turker Acikgoz[1*]

Abstract

Over the course of the last century, globalization and integration have increased significantly around the world. The rise in economic and financial globalization and integration has increased the connectedness between national economies and financial markets and secured an important place in the systemic risk spillover. It is important to analyze the issue in terms of different markets. Food prices around the world have increased significantly over the last 20 years. The price and volatility increase associated with food products lead to important socioeconomic and social problems. In this context, it will be important for decision-makers to assess the issue from the perspective of financial markets and to understand and reveal the dynamic structure of food commodity markets. This study aims to examine the connectedness of return and volatility in the Electronic Warehouse Receipt (EWR) market, where agricultural commodities are traded in Turkey, and to analyze its dynamic structure that changes over time. In this study, the Diebold-Yilmaz connectedness measurement method based on the forecast error variance decomposition after the VAR (p) model was used to analyze the connectedness between financial assets. According to the results of the static analysis performed, it was observed that while the return connectedness in the EWR market is very low, the volatility connectedness is at a higher level than the return connectedness. Based on the results of the dynamic analysis, no trend was observed in return connectedness; however, rapid increases and decreases were observed for certain periods. On the other hand, while an increasing trend was observed in the dynamic analysis of volatility connectedness, sudden increases and decreases were observed during periods of crisis. Of all agricultural commodities, it was observed that barley was the asset that sent the most net shock into the system. The EWR market in Turkey has come up recently. The market's structure, dynamics, and synchronization with other markets are still at a low level. The spillover effect of return and volatility shocks in the market are also low. The findings of this study can be used by producers, financial market participants and various decision makers for risk management, hedging and profit maximization purposes.

Keywords: Financial connectedness, Electronic warehouse receipts, Agricultural commodity market, Agricultural finance, Food prices volatility.

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Öz

Dünyada son yüzyıldan bu yana küreselleşme ve entegrasyon ciddi oranda yükselmiştir. Ekonomik ve finansal küreselleşme ve entegrasyondaki artış ülke ekonomileri ve finansal piyasalar arasındaki bağlantılılığı artırmakta ve sistematik riskin yayılmasında önemli bir yer tutmaktadır. Konunun farklı piyasalar özelinde incelenmesi önem arz etmektedir. Dünyada gıda fiyatları son 20 yılda önemli oranda artmıştır. Gıda ürünlerinde yaşanan fiyat ve volatilite artışları önemli sosyoekonomik ve toplumsal sorunları da beraberinde getirmektedir. Bu bağlamda konuya finansal piyasalar açısından bakmak ve gıda emtia piyasalarının dinamik yapısını anlamak ve ortaya koymak karar alıcılar açısından önemli olacaktır. Bu hedefle çalışmanın amacı Türkiye'de gıda emtialarının işlem gördüğü Elektronik Ürün Senedi (ELÜS) piyasasında getiri ve getiri volatilitesi bağlantılılığının incelenmesi ve zamanla değişen dinamik yapısının analizidir. Çalışmada finansal varlıklar arasındaki bağlantılılığın analizinde VAR (p) modeli sonrası tahmin hata varyans ayrıştırmasına dayalı Diebold-Yılmaz bağlantılılık ölçümü yöntemi kullanılmıştır. Gerçekleştirilen statik analiz sonuçlarına göre ELÜS piyasasında getiri bağlantılılığının oldukça düşük düzeyde iken volatilite bağlantılılığının getiri bağlantılılığına nazaran daha yüksek düzeyde var olduğu görülmüştür. Dinamik analiz sonucunda getiri bağlantılılığında herhangi bir trend görülmemiş, fakat belirli dönemlerde hızlı yükselişler ve düşüşler görülmektedir. Volatilite bağlantılılığının dinamik analizinde ise yükselen bir trend görülmekle birlikte kriz dönemlerinde ani yükseliş ve düşüşler görülmüştür. Tüm gıda emtiaları içerisinde sisteme en çok net şok yayan varlığın arpa olduğu görülmüştür. Türkiye'de ELÜS piyasası oldukça yakın bir geçmişe sahiptir. Piyasanın yapısı, dinamikleri ve diğer piyasalarla senkronizasyonu henüz düşük seviyededir. Piyasadaki getiri ve getiri volatilitesi şoklarının yayılma etkisi henüz düşük düzeydedir. Bu çalışmanın bulguları, üreticiler, finansal piyasa katılımcıları ve çeşitli karar alıcılar tarafından, risk yönetimi, hedge ve kar maksimizasyonu amaçlarıyla kullanılabilir.

Anahtar Kelimeler: Finansal bağlantılılık, Elektronik ürün senedi, Gıda emtia piyasası, Tarım finansmanı, Gıda Fiyatları volatilitesi

1. Introduction

The increase in the world population in the last century has reached inconceivable levels. The world population was 2.58 billion in 1951, and this figure has risen to 7.79 billion in 2020 (Worldometer, 2021). There has been a 200% increase in the world population within a period of only 70 years. This increase in the world population carries two important problems, namely, poverty and feeding the population. It is possible that the increase in the world population will support economic growth and development since the workforce will increase. However, in this case, it is necessary to solve the main problems brought along by population growth.

On the other hand, global food prices have been in an upward trend since the beginning of the 2000s. As of 2021, food prices in the world have increased by 126% in the last 20 years (FAO, 2021). Global warming and climate change, rise in oil prices, increase in population (Agizan ve Bayramoglu, 2021), and the consequent increase in demand (Negis et al., 2017) are among the most important reasons for the rise in global food prices (Chen et al., 2010).

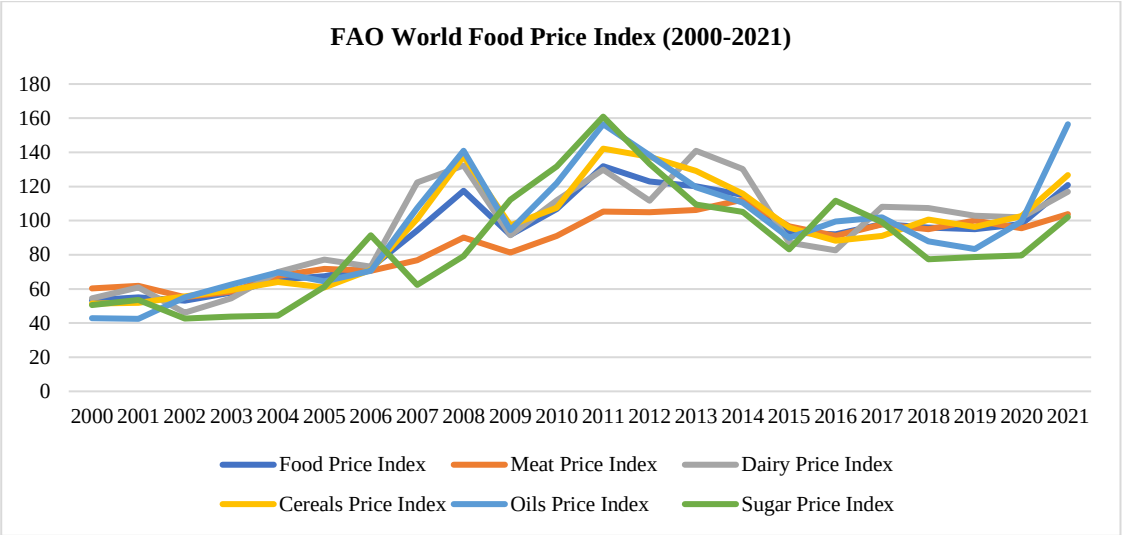

Figure 1. World food price index

The ongoing COVID-19 pandemic has led to a significant increase in global food prices. Since the beginning of the pandemic, many causes such as labor shortage and increase in demand due to reasons such as movement restrictions and pandemic measures, restrictions on global trade, and difficulty of people to access food products have led to serious increases and volatility in food prices (Laborde et al., 2020).

In this context, assessing the situation from the perspective of financial markets to understand the food prices that have increased since the beginning of 2000 and galloped during the COVID-19 period and the problems caused by the pandemic will contribute to the policy-making process of the stakeholders and decision-makers concerning this issue.

An important market where agricultural products are traded in Turkey is the Turkish Mercantile Exchange (TURIB). The TURIB, an organized market where securitized agricultural products are bought and sold in Turkey, was established in June 2018. The traded assets in TURIB are electronic warehouse receipts (EWRs), which is a new product for the Turkish financial markets and has emerged because of the securitization of agricultural products. The concept of warehouse receipts has been included in the literature for a long time. The warehouse receipts are defined as a valuable security that can be given as a guarantee, which is prepared by examining the class and standard of the products received by the warehouse in return for the agricultural products delivered to the licensed warehouses and represents product ownership (Cayir, 2019). These warehouse receipts can be issued and endorsed to name or order. On the other hand, EWRs refer to the electronic registration and storage transactions, which are created in accordance with the procedures and principles determined by the electronic registry agency and the Ministry of Commerce in return for agricultural products delivered to licensed warehouses (Cayir, 2019). EWRs are a type of securitized assets that enable the electronic recording of product securities and easy trading in financial markets.

The securitization of agricultural products as EWRs has several benefits. Some of these benefits can be listed as follows (Cayir, 2019):

- The classification of agricultural products as a financial asset increases their liquidity and turns them into a financial investment tool (Aydın, 2021). Thus, this classification creates an alternative investment tool and financing option within the scope of interest-free finance.
- EWRs are accepted as collateral by banks. Thus, it is possible for the farmer to access easy financing.
- The products are classified according to certain quality and standards by the markets where they are traded (TURIB). This classification makes important contributions to the buying and selling of products.
- Keeping the record of the product electronically and trading it in an organized market increases its liquidity and accelerates the financial transactions of agricultural products.
- Takasbank uses the international numbering system (ISIN – International Securities Identification Number) in the electronic classification of EWR products. Thus, EWRs issued by domestic licensed warehouses can be traded in financial markets around the worldwide.

It is important for developing agricultural commodity markets to understand and analyze the structure and dynamics of TURIB and EWRs. For this reason, in this study, the interactions of EWRs, whose underlying assets are wheat (durum wheat), barley, and corn, with return and volatility spillovers, are analyzed. These three products are chosen because they have been traded for the longest time without any interruption. For this purpose, we empirically investigate the connectedness and spillover effects of return and volatility shocks in the market.

Connectedness measurement and investigation of spillover effects are a type of analysis that has gained popularity in the literature on finance and economics recently. Developed by Diebold and Yilmaz (2009, 2012, 2014) and referred to by the same name, the Diebold-Yilmaz connectedness measurement (also known as the Diebold-Yilmaz spillover index) is mainly focused on measuring financial and macroeconomic connectedness. While the focus of financial connectedness is measuring the connectedness and spillover effects between different financial markets or financial products, macroeconomic connectedness generally concentrates on how shocks in different macroeconomic indicators, such as industrial production index, economic growth, unemployment, and inflation, expand through the countries and the spillover effects of international economic fluctuations.

Based on the studies of Diebold and Yilmaz (2009, 2012, 2014), the connectedness methodology is an econometric method that relies on a covariance-stationary Vector Autoregressive (VAR) model. The connectedness methodology basically uses the forecast error variance decomposition after a VAR model and exhibits that how shocks are transmitted in the system. With using the connectedness methodology, we can examine how the EWRs are connected to each other and how return and volatility shocks in the market are transmitted directionally (shocks from x_j to x_i and vice versa) and totally (shocks from x_j to all other x_i and vice versa). This study also uses the bootstrap rolling window approach, which enables us to analyze time-varying dynamics in these interactions.

There are many studies in the literature that investigate the connectedness of various financial assets, markets, or macroeconomic indicators. Being one of the pioneering studies in the literature, Diebold and Yilmaz (2009) measured the spillover effect of returns and volatility in 19 stock markets with a data set covering the period 1992–2007. The study shows that the effect of volatility spillovers among financial markets is higher than that of return spillovers. While return spillovers have an increasing trend, volatility spillovers do not follow any trend; however, bursts occur during crisis periods, followed by a rapid decline. In times of crisis, serious increases are observed in both return and volatility connectedness. Similar studies were performed by Yilmaz (2010) on the East Asian stock markets and by Diebold and Yilmaz (2011) on the stock markets of the countries in America, and corresponding results were obtained.

Diebold and Yilmaz (2012) measured the connectedness between different financial markets in the USA and the spillover effects of volatility shocks. In the study, volatility spreads between the stock market, debt market, foreign exchange market, and commodity market were analyzed, and it was observed that the main source of volatility shocks between the markets was the stock market. Additionally, the spillover effect of volatility shocks and the connectedness between the markets increased significantly during the periods of crisis. Similarly, In the study carried out by Diebold and Yilmaz (2014), the approach was combined with the network topology, and the connectedness between the 13

largest financial institutions of the USA was measured. As a result, they found a high level of volatility connectedness between the major financial institutions of the USA and showed that the connectedness reaches serious levels in times of crisis.

In the literature, many studies measure connectedness and spillover effects between financial markets and assets. Many of these researches on different markets, for instance; international equity markets (Barunik et al., 2016; Zhang, 2017; Demirer et al., 2018; Su, 2020; Diebold and Yilmaz, 2009; Polat, 2020), debt market (Alter and Beyer, 2014; Reboredo et al., 2020; Hussain Shahzad et al., 2019; Ferrer et al., 2021), commodity market (Antonakasis and Kizys, 2015; Balli et al., 2019; Uddin et al., 2019), cryptocurrency market (Corbet et al., 2018; Yi et al., 2018; Giudici and Pagnottoni, 2019; Ji et al., 2019; Li et al., 2020; Kliber and Wlosik, 2019), foreign exchange market (Antonakakis et al., 2020; Barunik and Kocenda, 2019; Bouri et al., 2020) and oil/energy market (Ferrer et al., 2018; Lovcha and Perez-Labardo, 2020; Toyoshima and Hamori, 2018; Hasan et al., 2021) detected high level of connectedness and spillover effects. On the other hand, some other studies have not found significant or low levels of connectedness and spillover effects in cryptocurrency markets (Trabelsi, 2018; Gillaizeau et al., 2019; Qarni et al., 2019; Balli et al., 2020) and oil/energy markets (Naeem et al., 2020; Zhang et al., 2020; Liu et al., 2020; Liu and Hamori, 2020; Balcilar and Usman, 2021).

In the literature review conducted, it was seen that the connectedness and spillover effects in the Electronic Warehouse Receipt market has not been investigated in any academic study yet. Within this context, the most important contribution of this study to the literature is the role of connectedness analysis in understanding the dynamics of the Electronic Warehouse Receipt market. Besides, the findings of this study have two important areas of usage for practitioners. First, producers can use the findings of this paper for operating risk management since this study exhibits how return and volatility shocks are transmitted between EWRs in the market, and stakeholders of TURIB can take action in this direction. Second, financial actors in the market can reap the benefit of this study for portfolio diversification and decision-making process since this study presents how return and volatility shocks are spread in the market and between assets.

2. Materials and Methods

In this section, first, the data of the study is introduced. Subsequently, the methods used in the measurement of return and volatility are explained, and finally, the connectedness analysis methodology, which is the main method used to achieve the aim of the study, is introduced. We conducted our analysis in two dimensions: return and volatility connectedness. Return connectedness exhibits that how return shocks are spread while volatility connectedness measures volatility shocks spills over the market.

2.1. Data

This study aims to measure the return and volatility connectedness of the Electronic Warehouse Receipt (EWR) market in Turkey and reveal the dynamics of the EWR market. In this context, commodities with underlying assets, such as wheat (durum), barley, and corn, which are traded for the longest time and have the highest trading volume in the Turkish Mercantile Exchange (TURIB), are used as the data set in the study. The return series and the volatility of the dataset are calculated over the closing prices of these three products for the 499 trading days between 30.07.2019 and 30.07.2021, and the analysis of connectedness between the commodities are performed. The data covers the period from the day that the market is first opened for trading to the day the analysis is completed.

2.2. Methods of measuring return and volatility

In return connectedness analysis, logarithmic return series of the data are used as the input of the VAR model. The calculation of the logarithmic return series is performed as follows in equation 1. In equation 1, $P_{i,t}$ stands for the price of i^{th} product at time t and $r_{i,t}$ stands for return of product i at time t.

$$r_{i,t} = \ln\left(\frac{P_{i,t}}{P_{i,t-1}}\right) \quad \text{(Eq.1)}$$

For volatility connectedness, we use realized conditional volatilities in the VAR system. To measure the EWR volatilities, a stochastic volatility model GARCH is applied. The GARCH (p,q) model is a method developed by Bollerslev (1986) and Taylor (1986) based on the work of Engle (1982), and it is used to measure volatility in

financial markets. The GARCH (p,q) model is calculated by modeling the volatility (σ_t^2) of a series by using the past deviations (u_{t-i}^2), and the past conditional variance (σ_{t-i}^2). The GARCH (p,q) process is addressed in equation 2.

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} a_i u_{t-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2 \quad \text{(Eq.2)}$$

GARCH (p,q) can be performed using different p and q values. However, empirical studies in the literature have demonstrated that the GARCH (1,1) method is usually the best model (Hansen and Lunde, 2005; Brooks, 2019). In this study, different GARCH (p,q) rankings were tried, and the best fit model to the volatility measurement of the return series is found to be GARCH (1,1). In the literature, different volatility measurement methods, such as those proposed by Garman and Klass (1980), Parkinson (1980), and Alizadeh et al. (2002) are recommended. However, these methods require the opening, closing, intraday high, and intraday low prices of the assets. In our study, instead of these methods, volatility measurement is applied using the GARCH (p, q) model due to the low trading volume of the EWR market and the observation that the intraday price movements are quite stagnant and in the form of sudden increases with large buy orders.

2.3. Diebold-Yilmaz connectedness measurement

Diebold-Yilmaz connectedness analysis is a method based on the forecast error variance decomposition after constructing a Vector Autoregressive (p) model, and it is used to measure how shocks spill over through the system. The method is based on studies conducted by Diebold and Yilmaz in 2009, 2012, and 2014. The method operates as follows:

A Vector Autoregressive model with constant covariance and N variables is as in equation 3.

$$x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \varepsilon_t \; ; \varepsilon_t \sim (0, \Sigma) \quad \text{(Eq.3)}$$

Since the VAR (p) model has fixed covariance, it complies with the invertibility rule, which is frequently used in time series, and can be written as an infinite-order moving average (MA) process. The infinite-order MA representation of the series is as follows.

$$x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-1} \quad \text{(Eq.4)}$$

The expression A_i in equation 4 represents the square coefficient matrix with a size of *N*N* and has the $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \ldots + \Phi_p A_{i-p}$ recursion formula. On the other hand, A_0 corresponds to the unit matrix with *N*N* dimensions, and when $i<0$, $A_i=0$. The MA coefficients and their variance decompositions in equation 4 play an important role in understanding the structure of the system. The connectedness method is based on variance decompositions, which helps in the decomposition of the forecast error variances at the H-step ahead of each variable in the system into parts that can be attributed to various system shocks.

Different methods are used for the variance decomposition. The most frequently used variance decomposition methods in the literature are Cholesky Decomposition and Generalized Impulse Response Function (GIRF). However, Cholesky Decomposition cannot give robust results as it gives varying results depending on the order of the variables. For this reason, in this study, the variance decomposition is performed using the GIRF algorithm, which is invariant to the order of the variables and based on the studies by Koop et al. (1996) and Pesaran and Shin (1998). In the variance decomposition using GIRF based on the VAR model, the share of the *j* in the H-step ahead forecast error variance decomposition of variable *i* for each H=1,2,3…, is as shown in equation 5.

$$\theta_{ij}^{g}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)^2} \quad \text{(Eq.5)}$$

In equation 5, Σ represents the variance matrix of the error vector, the symbol σ_{ii} represents the standard deviation of the i^{th} error term, while e_i represents the selection vector in which the i^{th} element is 1 and the others take the value 0. Although equation 5 performs the forecast error variance decomposition, the row sum does not yield 1 as the shocks directed to each variable are not orthogonal. Thus, normalization is required. The normalization process is described in equation 6.

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} \quad \text{(Eq.6)}$$

The total connectedness calculation can be performed with the results of the normalized variance decomposition. The total connectedness calculation is shown in equation 7. The total connectedness index (C(H)) shows the extent to which the shocks experienced in the returns or volatility of the assets spillover through the system.

$$C(H) = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} \quad \text{(Eq.7)}$$

Shocks from all other *j* variables to *i* variable are called "Contributions from Others (FROM)" and are calculated as in equation 8.

$$C_{i\leftarrow\blacksquare}(H) = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} * 100 = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} * 100 \quad \text{(Eq.8)}$$

Similarly, shocks directed from variable *i* to all other variables *j* are called "Contribution to Others (TO)" and are calculated as in equation 9.

$$C_{\blacksquare\leftarrow i}(H) = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\theta}_{ji}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ji}^{g}(H)} * 100 = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\theta}_{ji}^{g}(H)}{N} * 100 \quad \text{(Eq.9)}$$

The net total directional connectedness is measured as in equation 10. Net total directional connectedness (net spillovers) is calculated by netting the shocks from all other *j* variables to the *i* variable and the shocks from the *i* variable to all the other *j* variables. In short, it is the difference between the value calculated in equation 9 and the value calculated in equation 8.

$$C_i(H) = C_{\blacksquare\leftarrow i}(H) - C_{i\leftarrow\blacksquare}(H) \quad \text{(Eq.10)}$$

The final value calculated with the connectedness method is the measurement of net pairwise directional connectedness. Net pairwise directional connectedness is used to measure the net pairwise spillovers between the two variables. Net pairwise directional connectedness (net pairwise spillovers) is calculated as in equation 11.

$$C_{ij}(H) = C_{i\leftarrow j}(H) - C_{j\leftarrow i}(H) \quad \text{(Eq.11)}$$

3. Results and Discussion

When investigating return and volatility connectedness, the analyses are carried out as both static analysis and dynamic analysis. In static analysis, we run the model using a full-sample series. This full-sample connectedness provides a good perspective on average connectedness during the whole sample period. But it lacks to exhibit time-varying dynamics of spillovers. On the other hand, financial markets are dynamic. The relationships in the markets are stochastically determined and change over time. For this reason, we also model the dynamic structure of connectedness.

For dynamic analysis, we apply the bootstrap rolling-window approach to calculate time-varying (dynamic) connectedness. The bootstrap rolling-window approach is a statistical application used to overcome parameter non-constancy by running the econometric model with partitions of full-sample via setting sub-sample windows. By selecting a sub-sample rolling window with *K* observations, the full sample with *T* observations can be altered to a series of *T-K* sub-samples, in other words, ψ*-K+1*, ψ*-K*, …, *T* for ψ*=K, K+1*, …, *T* (Li et al., 2019). In the dynamic analysis, the window size (*K*) is set as 100 trading days, and the window sliding is performed by shifting one trading day in each analysis. As Kang et al. (2019) state, the harvest period for most of the agricultural crops, especially cereals, is about four months. Therefore, to allow the effect of harvest periods in price shocks, we set the window size as 100 trading days, which is nearly four months. Since the window size is set as 100 days when applying the rolling windows method, the first 100 days of the data set are lost in the dynamic analysis results. Therefore, dynamic analysis results show the dates between 25.12.2019-30.07.2021.

In the connectedness analysis, first, it is necessary to build the most optimum VAR (p) model. The analysis show that the VAR (9) model in return connectedness and the VAR (10) model in volatility connectedness are the best models according to the AIC and FPE information criteria. The forecast error variance decomposition is performed up to *H*=15 steps ahead in both return and volatility connectedness. After the *H*=15, no significant change is observed in the connectedness measurements.

3.1. Static return connectedness

The results of the static analysis of return connectedness are presented in *Table 1*.

Table 1. Return connectedness

	Barley	**Wheat**	**Corn**	**Contribution From Others (FROM Spillovers)**
Barley	92.3	3.12	4.54	7.65
Wheat	6.57	91.05	2.38	8.94
Corn	7.75	1.72	90.5	9.48
Contribution To Others (TO Spillovers)	14.3	4.86	6.93	
Net Spillovers	6.69	-4.08	-2.55	**Total Connectedness Index**=8.70%

In the connectedness table, the diagonal elements show to what extent the shocks experienced in the return of the Electronic Warehouse Receipt (EWR) asset in the row they correspond to are caused by internal shocks, and the last column of the table shows to what extent they are affected by external shocks. The "Contribution to Others" row shows the extent to which each EWR asset transmits shocks to other assets, while the "Net Connectedness" row demonstrates the difference between shocks to others and shocks from others. Finally, the Total Connectedness Index, located at the bottom right of the table, is an indicator that measures the extent to which return shocks are spread through the system.

In the EWR market, the return connectedness between assets is quite low. Shock spillovers within the system are about 8.70%. It is seen that the majority of the shocks in the returns of assets in the EWR market are due to the innovations experienced in the internal shocks of each asset, and the spillover of the return shocks between the assets is at a very low level. When the net spillovers are analyzed, all assets except barley EWRs have negative net spillovers, and the shocks they spread to others are more than the shocks from others. In terms of return connectedness, it can be said that the main product that causes a net shock in the market is barley.

3.2. Dynamic return connectedness

In the dynamic analysis of return connectedness, the measure of total connectedness is shown in *Figure 2*, net total connectedness in *Figure 3*, and net pairwise connectedness in *Figure 4*.

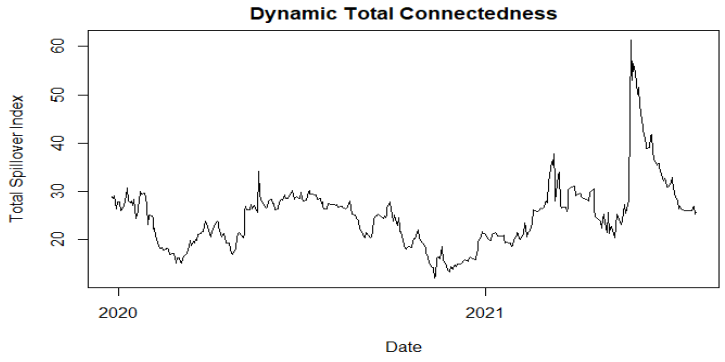

Figure 2. Dynamic total connectedness (return connectedness)

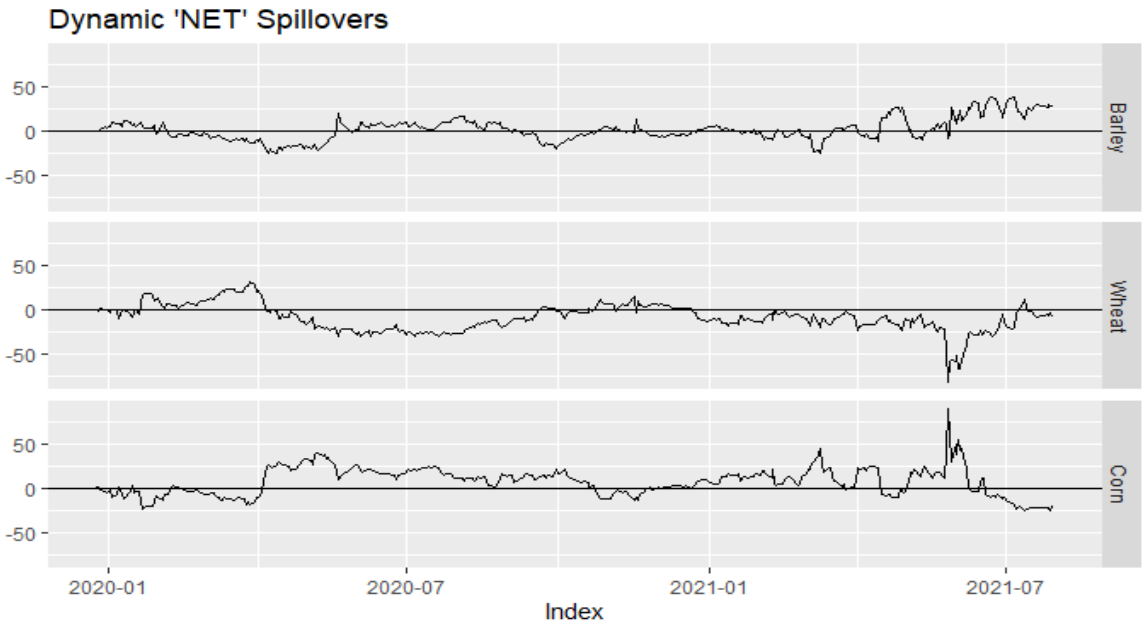

Figure 3. Dynamic net total connectedness (return connectedness)

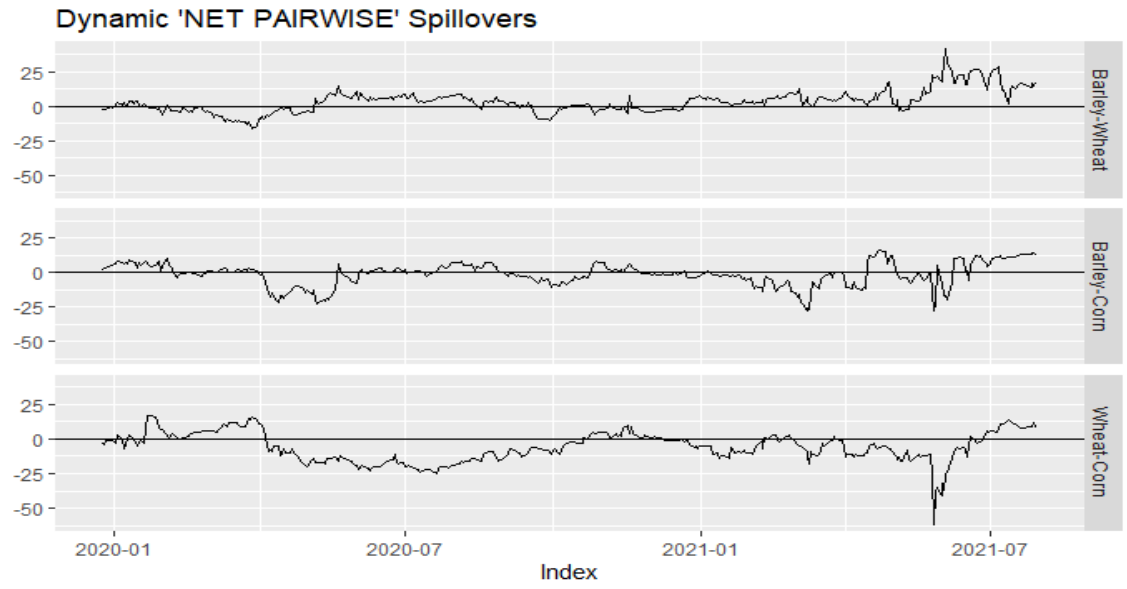

Figure 4. Dynamic net pairwise directional connectedness (return connectedness)

When the dynamic total connectedness analysis is examined, no trend is observed in the return connectedness. There was an abnormal increase in total connectedness between 25.05.2021 and 04.06.2021, but it decreased rapidly in the following days. In the EWR market, the connectedness between assets do not have an increasing trend. On the other hand, the spillovers increase in certain periods due to shocks. However, it is subsequently returning to its previous levels. Although it was experienced at a lower intensity, there were decreases after sudden increases in total connectedness during the period between the beginning of February 2021 to mid-April 2021. No significant impact from COVID-19 was observed on the measurements of total dynamic connectedness.

The net spillover of assets in *Figure 3* is very close to zero. Unlike the others, the net spillovers of corn EWRs are generally positive, but quite low. The effect of important innovations experienced in the period between the end of May 2021 and June 2021, also observed on the total connectedness, was seen, and the net positive spillover of corn and the negative spillover of wheat increased significantly during this period, and these two products exhibited an inverse correlation.

Net pairwise spillovers are shown in *Figure 4*. The net pairwise connectedness between all assets is very low except

for the period of abnormal increase defined above. In net pairwise connectedness between barley-wheat, the net pairwise shock transmission is usually from barley to wheat. The opposite can be said for the relationship between barley-corn. Finally, when the relationship between wheat and corn is analyzed, it is seen that corn is in a position that transmits the net shock to wheat, especially in the periods when there are sudden shocks to the system.

3.3. Static volatility connectedness analysis

When measuring volatility connectedness in the Electronic Warehouse Receipts (EWR) market, volatility must be measured first. Barley, wheat, and corn EWR volatilities are measured by GARCH (1,1), and the comparison between them is given in *Figure 5*. Although the dynamic volatility is low in barley EWRs, there are sudden increases in volatility in the period between mid-May 2021 and the first week of June 2021. The volatility of corn EWRs follows a similar course. Although there was a slight increase in wheat EWRs during the same periods, high volatility increases were not observed as in other assets. Unlike the others, in wheat EWRs, increases and decreases were observed on certain dates during the analysis period.

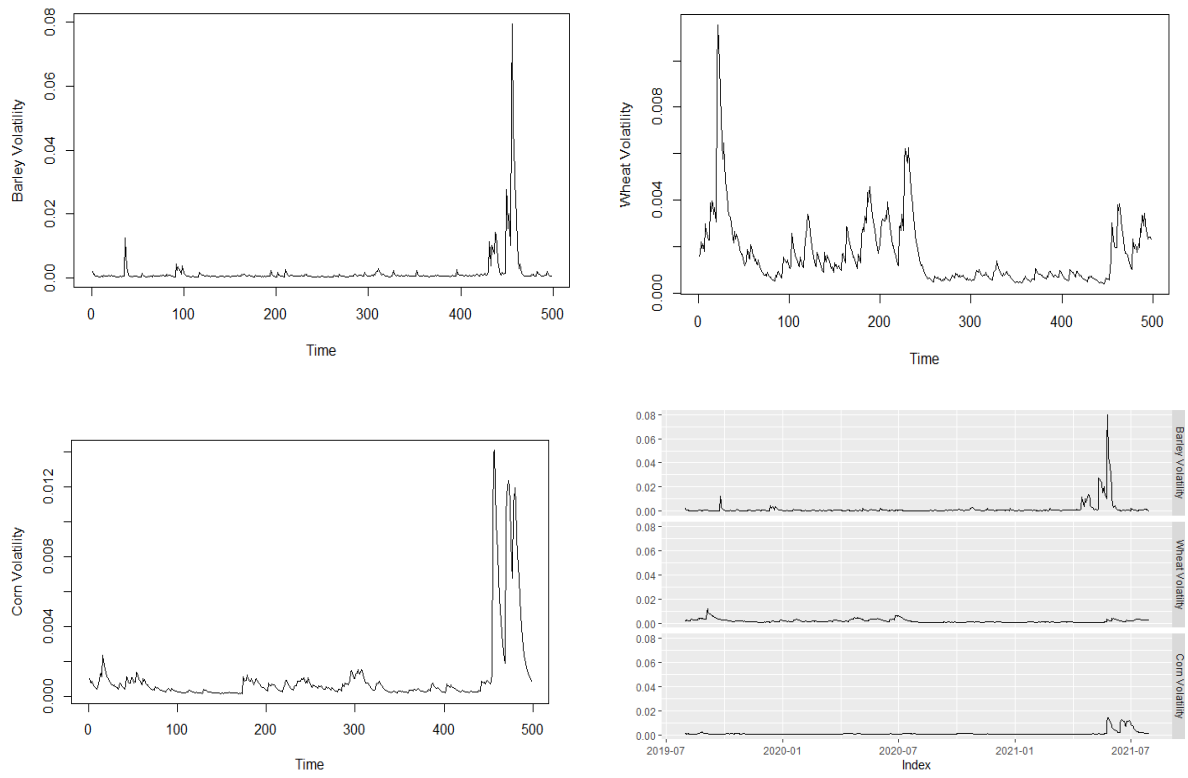

Figure 5. EWR volatilities

The results of the volatility measurements carried out using the results of GARCH (1,1) model. Static volatility connectedness measurements are given in *Table 2*.

Table 2. Volatility connectedness table

	Barley	**Wheat**	**Corn**	**Contribution From Others (FROM Spillovers)**
Barley	78.2	1.19	20.7	21.84
Wheat	3.15	92.8	4.05	7.2
Corn	30.5	0.31	69.2	30.84
Contribution To Others (TO Spillovers)	33.7	1.5	24.7	
Net Spillovers	11.9	-5.7	-6.12	**Total Connectedness Index**=19.97%

As seen in *Table 2*, the Total Connectedness Index is 19.97%. This figure indicates that 80.03% of the volatility shocks experienced in the EWR market are caused by the internal shocks of the assets, and 19.97% are due to the

volatility shocks (external shocks, spillover effects) experienced in the market due to the volatility shocks experienced in other assets. Compared to return connectedness, volatility connectedness is relatively high in the EWR market, while 78.2% of the volatility shocks experienced in barley EWRs are due to their own internal shocks. 21.84% of the volatility shocks to barley EWRs are due to the volatility shocks experienced in wheat and corn EWRs. Similarly, 92.8% of volatility shocks in wheat EWRs and 69.2% of volatility shocks in corn EWRs are caused by the assets' own internal shocks, while 7.2% and 30.84%, respectively, are due to volatility shocks to other assets. When the net connectedness is analyzed, barley has the highest net spillover, while other assets have negative net spillovers. In the EWR market, it is seen that the asset in the position of the net shock-transmitter in the system is barley, while the other assets are in the net shock-receiver position.

3.4. Dynamic volatility connectedness

The results of dynamic analysis of total volatility connectedness are given in *Figure 6*, the net total connectedness in *Figure 7*, and the net pairwise connectedness in *Figure 8*.

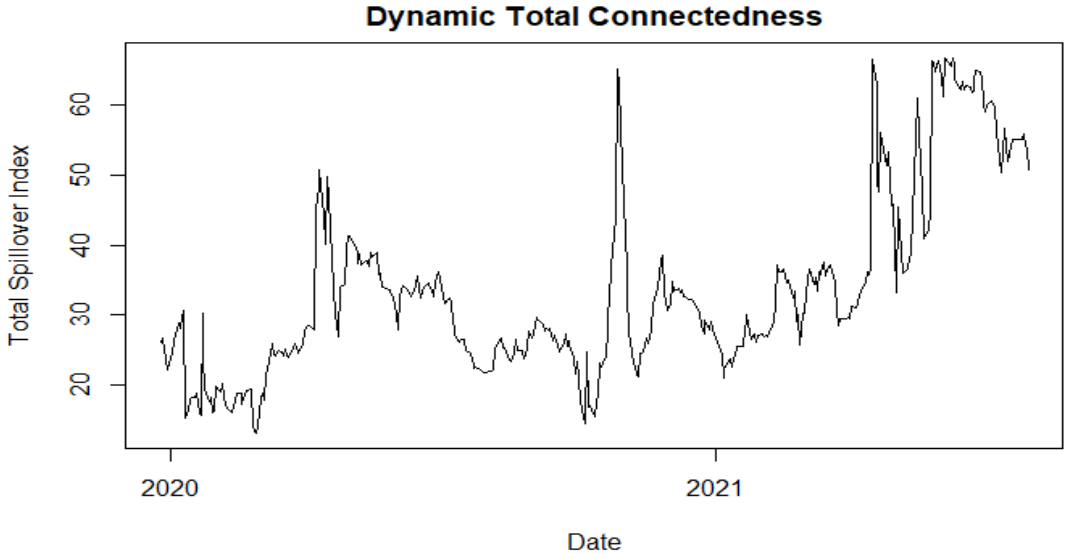

Figure 6. Dynamic total connectedness (volatility connectedness)

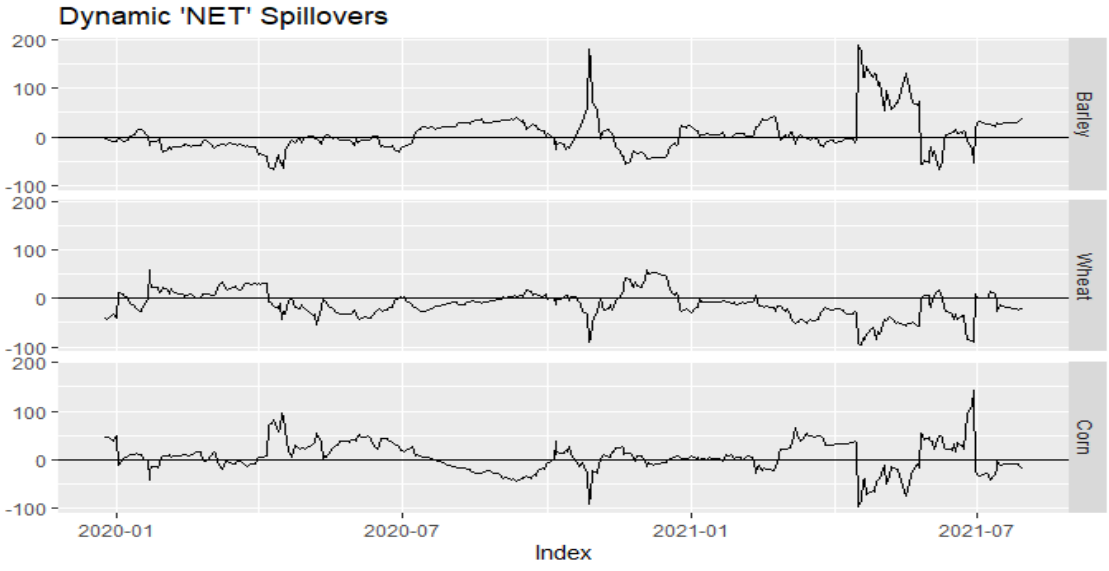

Figure 7. Dynamic net total connectedness (volatility connectedness)

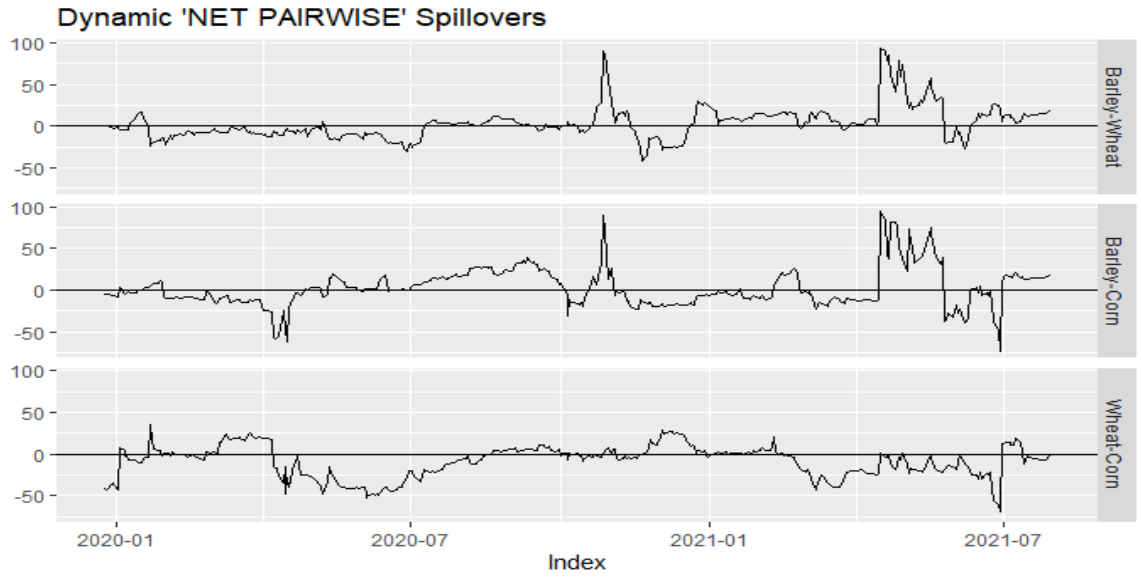

Figure 8. Dynamic net pairwise directional connectedness (volatility connectedness)

As shown in *Figure 6*, the dynamic analysis results of volatility connectedness are at a higher level compared to return connectedness. Compared to return connectedness, there is an exponential upward trend in volatility connectedness that starts in early October 2020. These periods coincide with the periods when there was a significant increase in cereal prices worldwide, and the increasing trend in prices started (See *Figure 1*). In addition to the spillovers of volatility shocks through the system, the trend includes sudden increases and decreases. Between 07/04/2020-17/04/2020 and 26/10/2020-30/10/2020, and 16/04/2021-07/05/2021, the volatility connectedness suddenly increased with a rapid decrease afterward. However, volatility connectedness, the process in which shocks propagated through the system increase as bursts and then transition to a sudden decline, demonstrates very short time intervals. The characteristic of the three-movement periods is that they are in the form of short-term sudden increase and decreases. The reasons for these were investigated and it is thought that they may be associated with Turkey's import of cereal products. It was observed that there were no significant movements in the Turkish financial markets (stock market, debt market, commodity, foreign exchange markets) during the aforementioned dates. It is believed that global food price fluctuations also do not have a significant effect, as a global effect would be expected to have longer-term effects, not such short-term effects. This is only the case with the increase in volatility spillovers in October 2020. This is because these periods coincide with the times when food prices in the world increased significantly, and they also create a significant upward trend in the following periods.

Finally, unlike other volatility bursts, serious increases were experienced in volatility connectedness on 17/05/2021 and the high level of connectedness continued. Contrary to return connectedness, the volatility connectedness analysis shows the effect of the periods when COVID-19 first appeared in Turkey. These periods coincide with the period of price shocks caused by the increase in demand on the dates when the curfews due to COVID-19 were announced both in Turkey and in the world.

The results of the dynamic net connectedness analysis are depicted in *Figure 7*. In the analysis of net spillovers, it is seen that there is a moderate negative correlation between barley and wheat and a high level of negative correlation between barley and corn. In the dynamic analysis, short but high-impact sudden increases seen in certain date ranges are also seen in net spillovers. In these periods, the main source of the spillover of volatility shocks in the system is the shocks in barley EWRs. Similar results are also observed in the net pairwise connectedness analysis. Net pairwise spillovers, which usually have a horizontal course, show sudden increases in certain periods due to shocks to the market. The volatility shocks experienced in barley EWRs during these periods significantly affect wheat and maize EWRs.

3.5. Discussions on findings

In the study, it is observed that the return connectedness in the EWR market is quite low, and although it has some upward movements in certain periods, it does not have any upward or downward trend. In this respect, our study found various results from the pioneer studies of Diebold and Yilmaz (2009), Yilmaz (2010), and Diebold and Yilmaz (2011)

on other financial markets. On the other hand, in the analysis of volatility connectedness, it is observed that an exponentially increasing trend has started in the connectedness of EWR assets in the market as of October 2020. While the effect of COVID-19 on the return connectedness is not observed, the effect of COVID-19 on the volatility connectedness can be seen in the April 2020 period when the first cases emerged in Turkey and the first full lockdown was imposed. However, contrary to return connectedness, there were sudden increases in volatility connectedness when there were shocks to the market, followed by rapid decreases. Similar types of behavior are not observed in volatilities. In this context, our study is in concordance with those studies in the literature (Diebold and Yilmaz, 2009; Yilmaz, 2010; Diebold and Yilmaz, 2011; Antonakakis and Kizys, 2015; Yi et al., 2018; Ji et al., 2019). The findings exhibit low return connectedness and high volatility connectedness in the market. These results could be arisen because EWR is a newly introduced concept and TURIB is a relatively a new and small market compared to other peers.

Previous studies (Diebold and Yilmaz, 2009; Yilmaz, 2010; Diebold and Yilmaz, 2011; Diebold and Yilmaz, 2012) showed that global risks and volatility shocks spread quickly in different markets or assets around the worldwide. However, return shocks and bull markets are more endogenous and occur domestically, either country-specific or market-specific. So, return connectedness is more domestic and lower than volatility connectedness, which are more influenced by global risks. Since TURIB is a small market yet, it may be more sensitive to external risks and volatilities occur in other national or global markets. Such external risks have increased enormously at the beginning of the COVID-19 pandemic. This could be the main reason for high volatility connectedness in the market. On the other hand, when we discuss low return connectedness, this finding could be due to the same fact that the EWR market is a small and quite new concept. Thus, agricultural-based financial assets and the actors in the EWR market have not significantly integrated in other global or national markets. This may be the reason why high return connectedness and the bull market movements in the global markets are not experienced in the TURIB market.

The result of the connectedness between the assets in the EWR market displayed that the main product in the market that transmits net shocks is barley EWRs. It is concluded that the main source of both return and volatility shocks in the TURIB market is barley EWRs. It is not surprising when Turkey's production data for cereals are investigated. According to Turkstat (2021), Turkey's barley production decreased over 30% while wheat decreased 13.9% and corn production increased 3.8% in 2021. Most of the data in our analysis cover years 2020 and 2021. Evaluating net and pairwise connectedness results with agricultural production changes in Turkey, we may comment that return and volatility shock-transmitter products are directly related with current and/or producers' and investors' expected future production amount. We may also comment that since these results first started in 2020, producers and actors in the market may have foresight about the future changes in production and take actions before. In the future periods, net total and net pairwise return and volatility shocks in the EWR market may be shaped in line with the current and/or expected future production amount.

4. Conclusions

In today's world, which has been globalizing and becoming highly integrated, the relations and synchronization between national economies, financial markets, and assets have significantly increased. This situation has created a highly connected economic and financial environment in which systematic risk and global economic/financial shocks are transmitted rapidly through different countries, financial markets, and assets. Understanding the connectedness of financial assets and markets has an important place in understanding the dynamics of financial markets, measuring the effects of these dynamics, managing risk, and foreseeing the future. Within this context, in this study, a connectedness analysis based on return and volatility series are performed using Diebold-Yilmaz connectedness analysis to understand the dynamics of Electronic Warehouse Receipts (EWR), a new asset in Turkish financial markets, and the Turkish Mercantile Exchange (TURIB). We conduct connectedness analysis on two-dimensions; return and volatility series. According to the findings of this study, there is a low level of connectedness in the returns of EWR assets. On the other hand, we detect that volatility shocks are highly spread across the market. Besides, there is an increasing trend in volatility connectedness. We believe that the above findings are related to the fact that both EWR assets and TURIB have a very recent history compared to other financial assets and markets in Turkey. Thus, EWR assets are significantly affected by external volatility shocks, whereas returns are more endogenous and market-specific. Another important finding of this study is that barley EWRs are the main source of return and volatility shock in the market. This could be because most recent statistics on Turkey's cereal production indicate enormous falls in barley production. Therefore, we believe that the dynamics of the EWR market are related to agricultural production amount of Turkey. Of course,

this hypothesis requires to be tested in future studies.

In addition to enriching literature by investigating connectedness and spillover effects in the EWR market, this study makes important contributions to practitioners in two perspectives. For producers, operational risk can be hedged using EWRs whose net pairwise spillovers are negatively correlated with producer's main crops. Such a wheat producer who wants to minimize its risk against price volatility can use corn EWRs and of course, vice versa is also true. Investors in the market can also apply the same strategy. Besides hedging price volatility risk, a similar perspective is also true for fixing profit according to return connectedness results. A barley producer who wants to minimize loss from its expected return can purchase wheat or corn EWRs since they have negative return spillovers. From the perspective of investors who seeks profit with lower risk can use the EWR market since return shocks spills over low-degree in the market, which is a great opportunity for portfolio optimization with other assets.

The EWRs and TURIB market is a new concept for Turkish financial markets. Additionally, the fact that TURIB is a new, low-recognized market where the trading of EWR assets does not have as large transaction volumes as other financial products and that is still a young market makes it difficult to understand the dynamics of this market. In the following periods, if the transaction volume expands and more investors turn to these products, the structure of the market will become clear, and changes in its dynamics will occur.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Agronomic Comparisons of Herbicides with Different Active Ingredients and Mechanical Hoeing for Weed Control in Oleic and Linoleic Type Sunflower (*Helianthus annuus* L.) Hybrids*

Oleik ve Linoleik Ayçiçeği Çeşitlerinde Yabancı Ot Mücadelesi İçin Uygulanan Farklı Aktif Madde İçerikli Herbisitler ve Mekanik Çapalama Yönteminin Agronomik Açıdan Karşılaştırılması

Fadul ÖNEMLİ[1]*, Ümit TETİK[2]

Abstract

Weeds cause serious yield losses in sunflower production. The most common methods for weed control are herbicide application and mechanical hoeing. The objective of this study was to determine the effects of five traditional herbicides containing different active ingredients compared with mechanical hoeing for weed control on seed yield components, seed oil content, and fatty acid composition in sunflower. Field experiments were conducted in the sunflower growing seasons of 2014 and 2015 on farmer fields in Karamusul village of Lüleburgaz, Kırklareli, located in the Northwest of Turkey (40°24' N, 27021 E and elevation 46 m). Pre-plant herbicide Bonoflan WG with benfluralin, pre-emergence herbicide Stomp®Extra with pendimethalin, and post-emergence herbicides Challenge600 with aclonifen and Targa Super with quizalofop-p-ethyl active were applied on non-Clearfield sunflower hybrids (P64LL05–Linoleic and P64H34–High oleic) while post-emergence herbicide Intervix®Pro with imazamox was applied on Clearfield hybrids (LG5542CL-Linoleic and Colombi–High oleic). In the results, the year effects were statistically significant on plant height, head diameter, number of days from planting to 50% flowering, and percentage of stearic acid of Clearfield cultivars while it was significant on plant height, head diameter, stem diameter, 1000 seed weight, number of days from planting to 50% flowering, seed yield, seed oil content, percentage of oleic and linoleic acids of non-Clearfield cultivars. The effect of genotype was significant for all seed yield and oil components except seed weight and seed yield for both groups' cultivars. Intervix®Pro caused significant decreases in plant height, stem diameter, and percentage of stearic acid. Stomp®Extra decreased the number of days from planting to 50% flowering. Challenge 600 had a negative effect on the seed oil content of P64H34 in 2015. There was no significant difference between herbicide applications and mechanical hoeing for seed yields except for increasing seed yield of P64H34 by Bonaflan WG in 2015. For all herbicide applications, residue in seeds was not exceeded international acceptable limits. According to the results, herbicides especially post-emergence applications under stress conditions can adversely affect agronomic yield and seed oil components in sunflower.

Keywords: *Helianthus annuus*, Herbicide, Hoeing, Seed yield, Oil content, Weed control.

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Öz

Yabancı otlar ayçiçeğinde ciddi verim kayıpları oluşturmaktadır. Yabancı otlarla mücadelede en çok kullanılan yöntemler herbisit uygulaması ve mekanik aletlerle çapalamadır. Bu çalışmanın amacı farklı aktif madde içeriğine sahip 5 ticari herbisit ile mekanik aletlerle yapılan çapalamanın ayçiçeğinin tane verimi unsurları, tane yağ içeriği ve yağ asitleri kompozisyonlarına etkilerini belirlemektir. Tarla denemeleri 2014 ve 2015 yıllarını kapsayan iki ayçiçeği yetiştirme mevsiminde Türkiye'nin kuzey batısında yer alan Kırklareli ilinin Lüleburgaz ilçesine bağlı Karamusul Köyünde (Enlem: 40°24' K, Boylam:27.021 D ve Rakım:46 m) çifti arazisinde yürütülmüştür. Araştırmada: çıkış sonrası kullanılan imazamox etken maddeli ticari Intervix®Pro herbisiti genetik Clearfield ayçiçeği hibriti çeşitlerine (LG5542CL-yüksek linoleik ve Colombi–yüksek oleik) uygulanmıştır. Ekim öncesi herbisitlerden benfluralin etken maddeli Bonoflan WG, çıkış öncesi herbisitlerden pendimethalin etken maddeli Stomp®Extra, çıkış sonrası kullanılan herbisitlerden aclonifen etken maddeli Challenge600 ve quizalofop-p-ethyl etken maddeli Targa Super ticari herbisitleri ise Clearfield geni taşımayan ayçiçeği hibrit çeşitlerine (P64LL05–yüksek linoleik ve P64H34–yüksek oleik) uygulanmıştır. Araştırma sonuçlarında; yıl faktörü Clearfield olmayan çeşitlerin bitki boyu, tabla çapı, sap çapı, 1000 tohum ağırlığı, ekimden %50 çiçeklenmeye kadar olan gün sayısı, tane verimi, tane yağ içeriği, oleik ve yağ asitleri içeriğine istatistiki önemli etkiye sahip olurken, Clearfield çeşitlerinde ise bu faktörün bitki boyu, tabla çapı, ekimden çiçeklenmeye kadar olan gün sayısı ve stearik asit üzerine olan etkileri istatistik anlamda önemli bulunmuştur. Genotip ise her iki grup için de tane verimi ve tane ağırlığı haricinde diğer ölçülen tüm verim ve yağ unsurları üzerinde istatistiki anlamda önemli etkiye sahip olmuştur. Intervix®Pro herbisitinin ayçiçeğinin bitki boyunda, sap çapında ve tohumlardaki yağın stearik asit içeriğinde düşüşlere neden olduğu belirlenmiştir. Stomp®Extra herbisiti ekimden %50 çiçeklenmeye kadar olan gün sayısını azaltarak erken çiçeklenmeye neden olmuştur. Challenge 600 ticari herbisiti ise 2015 yılında P64H34 çeşidinin tanelerindeki yağ oranının düşürmüştür. Tane verimi açısından Bonaflan WG hariç, herbisit uygulamaları ile mekanik çapalama arasında istatistiki açıdan önemli fark bulunamamıştır. Bonoflan WG ticari herbisitinin ise 2015 yılında P64H34 çeşidinde tane verimi üzerinde istatistiki açıdan önemli ve olumlu etkide bulunduğu belirlenmiştir. Tüm herbisit uygulamalarından hasatta elde edilen tane ürünlerinde yapılan pestisit analizlerinde limiti geçen bir değer bulunamamıştır. Araştırma sonuçlarına göre; herbisitler, stres koşullarında özellikle çıkış sonrası uygulamalarda ayçiçeğinin agronomik verim ve yağ unsurlarını olumsuz etkileyebilmektedir.

Anahtar Kelimeler: Çapalama, *Helianthus annuus*, Herbisit, Tohum verimi, Yabancı ot kontrolü, Yağ içeriği.

1. Introduction

Sunflower (*Helianthus annuus*) is one of the most important oilseeds with an annual 21.15 million metric tons of vegetable oil and 22.56 million tons of meal production in the world (USDA, 2021). Weeds are major yield-limiting factors and continue to pose a huge challenge for the production of sunflower. Sunflower is more vulnerable to weed competition during the first several weeks of growth than many other row crops (Soares et al., 2019; Kanatas, 2020). In the later growth stages, sunflower has an allelopathic potential to use for controlling weeds (Jabran, 2017). Crop yield decreases depending on weed population and sunflower growth stage are ranged from 10% to 70% (Delchev and Georgiev, 2015; Kanatas, 2020). Weed control in crop production is very important. The most common preferable method by the farmers for weeds is a chemical application which is economical in short term and has faster results to get rid of weeds. Pesticide use has become inevitable in agriculture and increased several folds during the last four decades.

Overuse of these chemicals has severe effects on the environment that may lead to immediate and long-term effects (Bhandari, 2014; Mingo, et al., 2016; Ferrante and Fearnside, 2020). Numerous studies have been carried out on the effects of pesticides on the environment and human health. Extensive or inappropriate use of pesticides by farmers can lead to the contamination of various ecosystems. Widespread distribution of pesticides is also known to cause problems with the apiculture and surface waters (Lari et al., 2014: Scholz-Starke et al., 2018; Wang et al., 2021). Since bees are the most important pollinators of crops, the use of pesticides can considerably reduce the yield of cross-pollinated crops (Önemli, 2005a; Önemli, 2005b; Barganska et al., 2014; Jumarie et al., 2017). The persistence of pesticides in soil and their residual effects on sequential crops have been reported by many researchers (Cassino et al., 2017; Çebi, 2018). Severe effects of herbicides have also been announced in agency reports of International Organizations (EFSA, 2014; FAO, 2019).

Herbicides also cause high phytotoxicity and damage to crops or non-target plants due to the wrong usage with technical implementation (Suryavanshi et al., 2015; Hasanuzzaman et al., 2020).

Mechanical weeding used alone or with herbicides in integrated weed control strategies also plays an important role in weed control (Pannacci and Tei, 2014). Although it is expensive, tedious, and time-consuming and also may cause root injury (El-Metwally and El-Wakeel, 2019) it has a minimum negative effect on human health and the environment according to chemical weed control.

The most of part of previous researches have been on the effectivity of herbicides for weed control in weed-crop competition (Elezovic et al., 2012; Selvakumar, 2018; Nicolae et al., 2019). Crop productivity in some of these researches was also measured in order to confirm the importance of successful weed control (Knezevic et al., 2013; Petcu and Ciontu, 2014; Suryavanshi et al., 2015; Jursík et al., 2020). A few studies have been conducted to determine the effects of herbicides on the seed yield, and some physiological and agronomical traits of sunflower under weed competition (Tawaha et al., 2002; Simic et al., 2011; Bharati et al., 2020; Mohapatra et al., 2020).

On the other hand, there is very low availability of data on comparisons between herbicide and mechanical hoeing weed control for the effects on the seed yield, seed oil content, fatty acids, and yield components such as flowering time, seed weight, plant height and head diameter in sunflower. The aim of the present study was to investigate the effect of five herbicides including different active ingredients applicated with respect to labeled dose and time making comparisons with hoeing weed control on seed yield, some yield components, seed oil content, and oil fatty acid profiles of two oleic and two linoleic sunflower hybrids. In addition, the herbicide residue of seeds for each application was determined whether it has exceeded the international limits.

2. Materials and Methods

2.1. Research area, soil properties, and meteorological data

Field experiments were conducted in two sunflower growing seasons including 2014 and 2015 on farmer fields in Karamusul village of Lüleburgaz, Kırklareli, located in the Northwest of Turkey (40°24’ N, 27.021 E and elevation 46 m). Kırklareli is one of the main sunflower-growing regions of Turkey. Some soil properties of experimental areas are given in *Table 1*. Soil properties in both years were similar. Soils of 2-yr field experiments were clay loam texture, neutral pH, and poor organic matter.

Table 1. Soil properties of experimental fields in 2014 and 2015

Year	SOM (%)	PH	Lime (%)	Salt (%)	N (%)	P_2O_5 ppm	K ppm	Ca ppm	Fe ppm	Mn ppm	Mg ppm
2014	1.92	6.7	0.57	0.07	0.08	14.28	212	4225	12.13	15.16	414
2015	1.88	6.8	0.68	0.08	0.09	14.36	228	4313	12.48	15.38	432

Table 2 shows some meteorological data during two sunflower growing seasons. In the second year, the beginning of the vegetative period and after R6 (flowering complete, ray flowers wilting) was very dry although all other vegetative and reproductive growth periods were very rainy in the first year.

Table 2. Some climatic data during growing periods of sunflower in 2014 and 2015.

Month	Rainfall (mm)		Relative humidity (%)		Temperature (^{0}C)	
	2014	2015	2014	2015	2014	2015
April	47.0	69.8	83.6	75.3	12.5	11.1
May	80.0	5.8	79.9	69.5	16.9	18.8
June	51.4	42.8	76.2	69.2	21.2	21.3
July	131.6	4.8	73.4	65.3	23.8	24.5
August	19.2	2.6	73.8	63.1	24.2	25.3
September	121.4	63.0	81.8	74.2	18.9	21.8

2.2. Plant materials

Table 3 shows some properties of traditional hybrids in this study. Two high oleic and two high linoleic sunflower hybrids were used. One of the oleic and linoleic hybrids was tolerant to imozamax herbicide in the Clearfield technology.

Table 3. Some properties of traditional sunflower hybrids in this study.

Sunflower hybrids	Seed company	Clearfield/non Clearfield	Oil fatty acid profile
LG 5542 CL	Limagrain	Clearfield	High Linoleic
P64LL05	Pioneer	Non-Clearfield	High Linoleic
Colombi	Syngenta	Clearfield	High Oleic
P64H34	Pioneer	Non-Clearfield	High Oleic

2.3. Application materials

Active ingredients, application rates, application times, trade names, and manufacturer of herbicides are given in *Table 4*. All herbicides were applied backpack sprayer at the recommended dose and time by their manufacturer.

Table 4. Active ingredients, application rates, application times, trade names, and manufacturer of herbicides

Trade name	Manufacturer	Active ingredients, per liter	Dose (ml/ha)	Application time
BonoflanWG	Dow AgroSciences	Benfluralin, 60 g	2500	Pre-Plant
Stomp® Extra	BASF	Pendimethalin, 450 g	3000	Pre-Emergence
Challenge600	Bayer	Aclonifen, 600 g	1250	Post-Emergence
Targa Super	Sumi Agro	Quizalofop-P-Ethyl,50 g	1000	Post-Emergence
Intervix® Pro	BASF	Imazamox, 40 g	1250	Post-Emergence

2.4. Experimental design and treatments

The trials were arranged separately for Clearfield and non-Clearfield cultivars in 2014 and 2015. Each experiment was laid out in a randomized complete block design (RCBD) with a split plot including different herbicide applications and mechanical hoeing for weed control on sunflower cultivars with four replications. “Intervix® Pro” was applied to Clearfield hybrids “LG 5542 CL” and “Colombi”. Other herbicides “BonoflanWG”, “Stomp® Extra”, “Challenge600” and “Targa Super” were applied to non-Clearfield hybrids “P64LL105” and “P64H34”. Each cultivar in replication also had a control plot as mechanical hoeing weed control.

Each plot was set up in planting at 5.0 m × 2.8 m = 14.0 m^2. Planting was done on May 21, 2014, for the first

year, and on April 27, 2015, for the second year with an intra-row spacing of 30 cm and a row-to-row spacing of 70 cm. The reason for the late planting in the first year was heavy rainfall. The experimental field each year was fertilized as 300 kg ha-1 with 20-20-0 (NPK) prior to planting. In each plot, plant height, the number of days from planting to 50 % flowering, head diameter, stem diameter, one thousand seeds weight, seed yield, oil content, and oil fatty acids were observed.

2.5. Analysis of pesticide residues

In addition, pesticide (herbicide) residues analysis were done on harvested seeds from each herbicide application plot within each block according to TS EN 15662 by a private firm. In analyses, GC MS/MS and LC MS/MS instruments were used for benfluralin, and pendimethalin, aclonifen and imazamox, respectively. UPLC MS/MS instrument was used to analysis of Quizalofop-P-Ethyl.

2.6. Statistical analysis

Statistical analysis was performed according to standard procedures for a randomized complete block design with split plots separately for Clearfield and non-Clearfield cultivars. The SAS System was used to generate the analysis of variance (ANOVA) for determining treatment effects on the dependent variables (SAS Institute, 1997). Treatment means comparisons were based on F-Protected Least Significance Differences (LSD) comparisons at $P \leq 0.05$.

3. Results and Discussion

In this research, the trials were arranged separately for Clearfield and non-Clearfield cultivars in 2014 and 2015. “Intervix® Pro” was applied to Clearfield cultivars “LG 5542 CL and Colombi”. Other four herbicides “Bonaflan WG, Stomp® Extra, Challenge600, and Targa Super” were applied to non-Clearfield cultivars “P64LL05 and P64H34”. Each cultivar had a control mechanical hoeing weed control on sunflower the plot within each replication. Thus, analysis of variance was done separately for Clearfield and non-Clearfield cultivars.

3.1. Analysis of variance (ANOVA) for sunflower yield and seed oil components

3.1.1. Variance analyses for seed yield and yield components in sunflower hybrids

Table 5. Analysis of variance of some seed yield and yield components in sunflower

Clearfield cultivars	**Plant height**	**Head diameter**	**Stem diameter**	**1000 seed weight**	**Days to 50% flowering**	**Test weight**	**Seed yield**
Y (Year)	3333.97**	4.22**	0.29	0.12	11.28*	0.01	290.65
C (Cultivar)	1275.00**	18.06**	2.31**	25.10	5.28*	24.67**	407.55
A (Application)	1933.33**	0.27	4.33**	45.13	2.53	0.34	293.79
Y*C	223.82**	0.11	0.49*	0.17	2.53	0.03	7378.08*
Y*A	0.24	0.45	0.11	0.25	0.03	9.14	50.45
C*A	12.09*	1.74	4.13**	4.96	1.53	0.14	13.49
Y*C*A	16.06*	1.24	0.07	0.01	0.03	0.02	0.22
CV	1.16	3.81	4.75	5.42	1.27	3.51	10.26
Non Clearfield cultivars	**Plant height**	**Head diameter**	**Stem diameter**	**1000 seed weight**	**Days to 50% flowering**	**Test weight**	**Seed yield**
Y (Year)	2472.87**	48.88**	1.62*	0.16	56.11**	0.61	63429.28**
C (Cultivar)	416.42**	177.40**	0.74*	164.37*	66.61**	1.46	2921.07
A (Application)	468.97**	0.77	1.18**	51.67	8.89**	4.22	1340.64
Y*C	0.08	2,96	0.46	0.77	3.61*	0.20	3015.35
Y*A	246.23**	0.35	0.09	0.31	0.46	0.56	563.62
C*A	398.21**	3.66	1.92**	193.2**	9.27**	3.18	523.25
Y*C*A	269.81**	1.14	0.33	0.82	1.33*	0.55	1052.91
CV	2.11	9.83	7.17	7.22	1.00	3.81	14.37

* and ** : Significant differences are shown at P < 0.05 and P < 0.01, respectively

Variance analyses of sunflower seed yield and yield components are given separately for Clearfield and non-Clearfield cultivars in *Table 5*. Plant height was significantly affected by year, cultivar, application, and interactions of year x application, cultivar x application, and year x cultivar x application in Clearfield and non-Clearfield cultivars. Only, year and cultivar had a significant effect on head diameter in both groups. Stem diameter was affected significantly by cultivar, application, year x application, and cultivar x application in Clearfield hybrids while the significant effective factors were the year, cultivar, application, and cultivar x application in non-Clearfield hybrids. There was no significant effective factor on 1000 seed weight in Clearfield cultivar, although cultivar and cultivar x application factors had a significant effect on this character in non-Clearfield cultivars. In Clearfield hybrids, year and cultivar had a significant effect on days from planting to 50% flowering time. On the other hand, the character was significantly affected by year, cultivar, application, and interactions of year x cultivation, cultivar x application, and year x cultivar x application in non-Clearfield hybrids. For test weight, only the cultivar effect was significant in Clearfield hybrids. It was not found effective factor on test weight for non-Clearfield hybrids. Year x cultivar and year had significant effects on seed yield in Clearfield and non-Clearfield hybrids, respectively.

3.1.2. Variance analyses for seed oil content and fatty acids in sunflower

Variance analyses of sunflower oil content and fatty acids are given separately for Clearfield and non-Clearfield cultivars in *Table 6*.

Table 6. Analysis of variance of seed oil content and percentage of fatty acids in sunflower

Clearfield cultivars	**Seed oil content**	**C16:0 Palmitic acid**	**C18:0 Stearic acid**	**C18:1 Oleic acid**	**C18:2 Linoleic acid**
Y(Year)	5.07	0.17	1.42**	28.28	23.21
C (Cultivar)	30.69**	14.20**	1.22**	13763.9**	12667.2**
A(Application)	0.99	0.03	0.06*	1.04	1.66
Y*C	2.14	0.27*	0.33**	0.63	0.47
Y*A	1.62	0.12	0.01	13.55	7.73
C*A	0.12	0.14	0.03	0.13	0.34
Y*C*A	0.01	0.05	0.03	37.37*	41.29*
CV	3.39	4.61	3.45	4.69	10.18
Non-Clearfield cultivars	**Seed oil content**	**C16:0 Palmitic acid**	**C18:0 Stearic acid**	**C18:1 Oleic acid**	**C18:2 Linoleic acid**
Y(Year)	257.22**	0.01	0.01	449.07**	654.25**
C (Cultivar)	289.98**	77.36**	13.3**	42187.6**	38949.1*
A(Application)	5.71	0.13	0.10	16.12	0.84
Y*C	61.65**	0.57	0.37*	19.52	5.09
Y*A	5.87	0.15	0.05	14.24	1.55
C*A	15.30*	0.35	0.07	20.74	5.96
Y*C*A	13.93**	0.38	0.04	19.01	7.08
CV	5.22	9.33	8.61	8.54	12.77

* and **: Significant differences are shown at P < 0.05 and P < 0.01, respectively

Differences between cultivars for seed oil content were significant in both groups. In addition to this factor, year, year x cultivar, cultivar x application, and year x cultivar x application had significant effects on seed oil content in non-Clearfield cultivars. Cultivar had also a significant effect on the percentage of palmitic acid in both groups. In Clearfield cultivars, a significant effect was also found for year x cultivar interactions. Year, cultivar, application, and year x cultivar interaction had a significant effect on the percentage of stearic acid in Clearfield cultivars, although the character was affected significantly by cultivar and year x cultivar interactions in non-Clearfield cultivars. Percentage of oleic and linoleic acids were affected by cultivar and year x cultivar x application interaction in Clearfield cultivars, while cultivar and year had a significant effect on these fatty acids in non-Clearfield cultivars.

3.2. Mean comparisons of yield and oil components for factors

3.2.1. Means of applications according to years for seed yield and yield components

According to year variation for Intervix®Pro herbicide application (*Table 7*), plant height and head size in 2015 were smaller than in 2014. In addition, in the second year, the number of days from planting to 50% flowering was decreased. Although planting in 2015 was about one month early than in 2014, this is thought to be caused by the low rainfall until the flowering in the second year. In other herbicide group cultivars, stem diameter was also decreased in addition to these characters. On the opposite of this, the seed yield of non-Clearfield cultivars significantly increased in 2015. It is thought that this could be due to the fact that the second group varieties enter the generative period earlier than the first group and make better use of the advantage of benefiting from soil moisture with early planting and escape from higher temperatures during grain filling (Soriano et al., 2004; Pepo and Novak, 2016; Debake, et al., 2017).

Table 7. Means of applications according to years for seed yield and yield components

Herbicide	Year	Plant height (cm)	Head diameter (cm)	Stem diameter (cm)	1000 seed weight (g)	Days to 50% flowering (days)	Test weight (kg/hl	Seed yield (kg ha^{-1})
Intervix® Pro	2014	149.24a*	18.88a	5.93	68.86	76.13a	34.91	2287.30
	2015	128.82b	18.15b	5.74	68.73	74.94b	34.88	2366.10
	LSD	1.19	0.52	0.20	2.74	0.71	0.90	175.7
Other herbicides**	2014	128.13a	16.30a	5.84a	73.91	72.25a	34.79	1782.0b
	2015	117.00b	14.74b	5.56b	73.82	70,58b	34.61	2359.3a
	LSD	1.16	0.68	0.18	2.39	0.32	0.59	132.7

*: Within each column in each group, means followed by the same letters are not significantly different at $P \leq 0.05$.
**: Bonoflan WG, Stomp® Extra, Challenge600, Targa Super

3.2.2. Means of applications according to years for seed oil content and fatty acids

In seed oil content and fatty acids of Clearfield cultivars (*Table 8*), there were no statistically significant differences between 2014 and 2015. Unlike that, seed oil content and percentage of linoleic acid in second-year non-Clearfield cultivars were lower than in the first year. Onemli (2012a) and Onemli (2012b) suggested that high temperatures and drought stress caused decreases in seed oil content and the percentage of linoleic acid in sunflower seed oil. Although they were not statistically significant in Clearfield cultivars, seed oil contents and percentage of linoleic acid in seed oil in 2014 depend on higher rainfall and lower temperatures were higher than in 2015.

Table 8. Means of applications according to years for seed oil content and fatty acids

Herbicide	Year	Seed oil content (%)	C16:0 Palmitic acid (%)	C18:0 Stearic acid (%)	C18:1 Oleic acid (%)	C18:2 Linoleic acid (%)
Intervix® Pro	2014	42.67	4.96	2.94a	60.70	29.70
	2015	41.87	5.10	2.51b	62.46	28.00
	LSD	1.05	0.17	0.07	2.13	2.16
Other herbicides**	2014	44.04a*	4.63	3.01	59.95b	30.82a
	2015	40.46b	4.64	3.00	64.69a	25.11b
	LSD	0.99	0.19	0.12	2.38	1.60

: Within each column in each group, means followed by the same letters are not significantly different at $P \leq 0.05$.: BonoflanWG, Stomp® Extra, Challenge600, Targa Super

3.2.3. Means of applications according to cultivars for seed yield and yield components

Table 9 shows cultivar variations for seed yield and yield components. High oleic Clearfield genotype "Colombi" had statistically higher plant height, head diameter, days from planting to 50% flowering and test weight, and lower stem diameter than "LG5542CL" cultivar. The high oleic non-Clearfield cultivar "P64H34" had higher plant height, stem diameter, 1000 seed weight, days from planting to 50% flowering, test weight and seed yield, and lower head diameter than "P64LL05" cultivar. Pepo and Novak (2016) put similar correlations between photosynthetic traits and yield depending on genotype in sunflower.

Table 9. Means of applications according to cultivars for seed yield and yield components

Herbicide	Cultivar	Plant height (cm)	Head diameter (cm)	Stem diameter (cm)	1000 seed weight (g)	Days to 50% flowering (days)	Test weight (kg/hl	Seed yield (kg ha^{-1})
Intervix® Pro	LG5542CL	132.72b	17.76b	6.11a	69.68	75.13b	34.01b	2295.2
	Colombi	145.34a*	19.26a	5.57b	67.91	75.94a	35.77a	2358.2
	LSD	1.19	0.52	0.20	2.74	0.71	0.90	175.7
Other herbicides**	P64LL05	120.29b	17.01a	5.60b	72.43b	70.50b	34.56b	1976.4b
	P64H34	124.85a	14.03b	5.80a	75.29a	72.33a	34.83a	2164.9a
	LSD	1.16	0.68	0.18	2.19	0.32	0.59	132.7

*: Within each column in each group, means followed by the same letters are not significantly different at P ≤ 0.05.
**: BonoflanWG, Stomp® Extra, Challenge600, Targa Super

3.2.4. Means of applications according to cultivars for seed oil content and fatty acids

Table 10 shows high linoleic genotypes (LG5542CL and P64LL05) in both groups with higher oil content in seeds than high oleic genotypes (Colombi and P64H34). The oleic types have been developed recently and the genetic resource in this type for oil and yield improvement is very poor compared to the linoleic types (Zhou, et al., 2018). There were known differences between the oleic and linoleic types in terms of fatty acids. But, both linoleic types had a higher percentage of oleic acids and a lower percentage of linoleic acids than their normal properties depending on higher temperatures (Onemli, 2012a; Onemli, 2012b)

Table 10. Means of applications according to cultivars for seed oil content and fatty acids

Herbicide group	Cultivar	Seed oil content (%)	C16:0 Palmitic acid (%)	C18:0 Stearic acid (%)	C18:1 Oleic acid (%)	C18:2 Linoleic acid (%)
Intervix® Pro	LG5542CL	43.25a	5.70a	2.92a	40.85b	48.75a
	Colombi	41.29b	4.36b	2.53b	82.32a	8.96b
	LSD	1.05	0.17	0.07	2.13	2.16
Other herbicides**	P64LL05	44.16a	5.62a	3.41a	39.36b	50.03
	P64H34	40.35b	3.65b	2.59b	85.28a	5.90
	LSD	0.99	0.19	0.12	2.38	1.60

*: Within each column in each group, means followed by the same letters are not significantly different at P ≤ 0.05.

3.2.5. Means of applications according to subjects for seed yield and yield components

Variations in seed yield and yield components by herbicide application are given in *Table 11*. Intervix®Pro herbicide had a negative effect on plant height and stem diameter in Clearfield cultivars. The effects of this herbicide on seed yield or other yield characters were not found significant.

In non-Clearfield cultivars, the shortest plant height was observed in the control application (hoeing weed control) while Stomp®Extra and Targa Super applications were in the highest plant height group. Bonaflan WG and Challenge600 had also higher plant heights than hoeing weed control. There was no significant group for head diameter in non-Clearfield cultivars. Stomp®Extra had the highest stem diameter. Challenge600 and Targa Super had also higher stem diameters than hoeing weed control. For 1000 seed weight, all herbicide applications were in the same group as hoeing weed control applications although two significant groups were observed. Days from

planting to 50% percent were decreased by Stomp®Extra application. Other herbicide applications were in the same group with hoeing weed control for this character. All herbicide applications for test weight and seed yield were also in the same group as hoeing weed control applications although there were two significant groups. Seed yield in Bonaflan WG was significantly higher than Targa Super.

Table 11. Means of applications according to subjects for seed yield and yield components

Clearfield cultivars	**Plant height (cm)**	**Head diameter (cm)**	**Stem diameter (cm)**	**1000 seed weight (g)**	**Days to 50% flowering (days)**	**Test weight (kg/hl)**	**Seed yield (kg ha^{-1})**
Hoeing	146.80a*	18.61	6.20a	67.61	75.25	34.99	2437.98
Intervix® Pro	131.26b	18.42	5.47b	69.98	75.81	34.79	2377.38
$LSD_{0.05}$	1.19	0.52	0.20	2.74	0.71	0.90	181.68
Non-Clearfield cultivars	**Plant height (cm)**	**Head diameter (cm)**	**Stem diameter (cm)**	**1000 seed weight (g)**	**Days to 50% flowering (days)**	**Test weight (kg/hl)**	**Seed yield (kg ha^{-1})**
Hoeing	113.96c	15.82	5.38c	73.79ab	72.06a	34.75ab	2036.5ab
Bonaflan WG	122.34b	15.49	5.54bc	76.25a	71.63a	34.89a	2251.3a
Stomp® Extra	126.43a	15.40	6.10a	71.78b	70.13b	35.25a	2147.6ab
Challenge600	122.25b	15.25	5.79b	74.94ab	71.69a	33.86b	2100.7ab
Targa Super	127.86a	15.64	5.69b	72.55ab	71.56a	34.74ab	2028.2b
$LSD_{0.05}$	1.83	1.08	0.29	3.77	0.51	0.94	214.95

*: Within each column in each group, means followed by the same letters are not significantly different at $P \leq 0.05$.

3.2.6. Means of applications according to subjects for seed oil content and fatty acids

Variations in seed oil content and fatty acids by herbicide application are given in *Table 12*. It was determined significant group for the only percentage of stearic acid in Clearfield cultivars. The percentage of stearic acid rate in seed oil was decreased significantly by Intervix®Pro application according to hoeing weed control. In non-Clearfield cultivars, herbicide applications did not create significant groups in seed oil content and fatty acids.

Table 12. Variations in seed oil content and fatty acids by herbicide application

Clearfield cultivars	**Seed oil content (%)**	**C16:0 Palmitic acid (%)**	**C18:0 Stearic acid (%)**	**C18:1 Oleic acid (%)**	**C18:2 Linoleic acid (%)**
Hoeing	42.09	5.06	2.77a*	61.76	28.62
Intervix® Pro	42.44	5.00	2.68b	61.40	29.08
$LSD_{0.05}$	1.05	0.17	0.07	2.13	2.16
Non-Clearfield cultivars	**Seed oil content (%)**	**C16:0 Palmitic acid (%)**	**C18:0 Stearic acid (%)**	**C18:1 Oleic acid (%)**	**C18:2 Linoleic acid (%)**
Hoeing	42.31	4.58	2.90	63.21	27.61
Bonaflan WG	42.63	4.78	3.09	60.59	28.08
Stomp® Extra	42.32	4.61	3.06	62.47	28.12
Challenge600	41.24	4.65	3.00	62.72	27.87
Targa Super	42.76	4.55	2.95	62.61	28.16
$LSD_{0.05}$	1.56	0.31	0.18	3.77	2.53

*: Within each column in each group, means followed by the same letters are not significantly different at $P \leq 0.05$.

3.2.7. Means of applications according to year and cultivar interaction for some seed yield and oil characters

Variations in seed yield and oil characters by herbicide applications depending on year and cultivar are given in *Table 13*. Intervix®Pro application had no significant effect on seed yield in both cultivars and both years. This herbicide increased the number of days from planting to 50% flowering according to hoeing weed control in LG 5542CL in 2015. Intervix®Pro decreased plant height in LG 5542CL and Colombi hybrids in both years. Seed oil content, percentage of oleic acid, and linoleic acid were not affected as statistically significant by Intervix®Pro application similar seed yield.

Table 13. Means of applications according to year and cultivar interaction for seed yield and oil characters

Cultivar	Year	Application	Seed yield (kg ha^{-1})	Days to 50% flowering	Plant height (cm)	Seed oil content (%)	C18:1 Oleic acid	C18:2 Linoleic acid
LG 5542CL	2014	Hoeing	2445.2	75.50	149.46a	44.03	41.67	47.73
		Intervix® Pro	2542.2	76.50	131.10b	43.78	37.98	51.23
		$LSD_{0.05}$	451.3	3.18	7.00	2.37	9.49	8.83
	2015	Hoeing	2275.4	73.75b	132.75a	42.23	40.25	49.52
		Intervix® Pro	2225.2	74.75a	117.56b	42.95	43.48	46.51
		$LSD_{0.05}$	274.1	0.99	2.24	4.23	4.62	4.44
Colombi	2014	Hoeing	2224.2	76.25	164.73a	41.40	81.40	10.24
		Intervix® Pro	2298.6	76.25	151.66b	41.46	81.77	9.62
		$LSD_{0.05}$	405.4	1.30	1.30	3.51	8.26	8.99
	2015	Hoeing	2614.9	75.50	140.27a	40.71	83.73	7.05
		Intervix® Pro	2635.8	75.75	124.71b	41.59	82.38	8.96
		$LSD_{0.05}$	290.2	0.80	2.35	3.16	2.33	2.80
P64LL05	2014	Hoeing	1810.1	71.75	117.13d	44.55b	38.16	51.73
		Bonaflan WG	1783.1	71.50	122.00c	44.45b	36.46	52.91
		Stomp® Extra	1691.2	71.00	123.82c	45.08ab	34.58	54.94
		Challenge600	1683.6	71.50	128.46b	45.21ab	38.40	51.30
		Targa Super	1579.4	72.00	137.68a	46.07a	34.87	54.84
		$LSD_{0.05}$	299.2	1.55	2.19	1.12	4.78	4.34
	2015	Hoeing	2303.8	69.75b	115.10b	42.70	42.57	46.68
		Bonaflan WG	2461.0	68.75c	111.76c	42.87	42.10	47.43
		Stomp® Extra	2461.0	68.75c	111.76c	43.50	42.01	46.69
		Challenge600	2338.0	68.75c	110.89c	44.34	41.84	47.07
		Targa Super	2413.2	71.25a	124.28a	42.79	42.58	46.72
		$LSD_{0.05}$	451.4	0.69	2.36	3.43	3.30	3.66
P64H34	2014	Hoeing	1746.0	74.25a	121.80c	43.01ab	83.23	8.61
		Bonaflan WG	1962.6	73.75a	135.22b	43.61a	83.15	8.98
		Stomp® Extra	2108.9	71.00c	135.32b	42.88ab	84.80	7.27
		Challenge600	2061.2	73.50ab	139.28a	43.00ab	82.10	9.59
		Targa Super	1886.9	72.25bc	120.57d	42.59b	83.76	8.09
		$LSD_{0.05}$	467.4	1.25	1.16	0.97	9.73	9.26
	2015	Hoeing	2286.1b	72.50a	101.80d	38.98a	88.87	3.41
		Bonaflan WG	2798.4a	72.50a	120.39b	39.58a	80.67	3.00
		Stomp® Extra	2329.4b	69.75c	134.83a	37.82ab	88.48	3.57
		Challenge600	2320.1b	73.00a	110.37c	32.42b	88.53	3.51
		Targa Super	2233.3b	70.75b	128.91a	39.59a	89.24	2.97
		$LSD_{0.05}$	447.6	0.51	7.17	5.78	12.29	1.63

*: Within each column in each group, means followed by the same letters are not significantly different at $P \leq 0.05$.

In non-Clearfield cultivars, Bonaflan WG increased seed yield according to hoeing weed control in P64H34 in 2015. In this group, there was no significant group in seed yield for applications for P64H34 in 2014, and for P64LL05 in both years. Targa Super had the highest number of days from planting to 50% flowering in the second year of P64LL05 hybrid although other herbicide applications (Bonaflan WG, Stomp®Extra and Challenge600) in this group caused early flowering than hoeing weed control. Stomp®Extra and Targa Super applications on P64H34 hybrid decreased the number of days from planting to 50% flowering according to hoeing weed control in both years. Targa Super application on P64LL05 gave the highest plant height in both years. Hoeing weed control had the shortest plant height for this hybrid in the first year while it was in the second-highest plant height group in 2015. For plant height of P64H34, Challenge600 had the highest value in 2014, while Stomp®Extra and Targa Super were in the highest plant height group. In the first year, Bonaflan WG. Stomp®Extra had higher plant heights than hoeing weed control in P64H34. In the second year, the plant height of hoeing weed control for P64H34 was the shortest within all applications. Targa Super application on P64LL05 in 2014 gave higher seed oil content than hoeing weed control although the other applications were in the same group as the control application. There was no significant difference between herbicide applications except Challenge600 and hoeing weed control for seed oil content of P64H34. There was no significant group for the percentage of oleic and linoleic acids in non-Clearfield hybrids.

3.3. Pesticide residues in harvested seeds of herbicide application plots.

Pesticide residues in harvested seeds of herbicide application plots are given in *Table 14*. The detected residue of herbicide active ingredients in the seed of herbicide application plots was not exceeded international acceptable limits.

Table 14. Pesticide residues in harvested seeds of herbicide application plots.

Trade name	Limit (LOQ)	Unit	Result	Instrument Analysis method
BonoflanWG	0.01	mg/kg	Not Detected	GC MS/MS TS EN 15662
Stomp® Extra	0.01	mg/kg	Not Detected	LC MS/MS TS EN 15662
Challenge600	0.01	mg/kg	Not Detected	LC MS/MS TS EN 15662
Targa Super	0.01	mg/kg	Not Detected	UPLC MS/MS J. of AOAC Int. vol. 90. No.2.2017
Intervix® Pro	0.01	mg/kg	Not Detected	LC MS/MS TS EN 15662

4. Discussion

According to results, the application of Intervix®Pro including 40 g/l Imazamox active ingredients caused decreases in plant height and stem diameter and increases the percentage of stearic acid in seed oil according to hoeing weed control in sunflower.

In comparison with hoeing weed control, the application of Bonaflan WG including 60 g/l Benfluralin active ingredients increased the seed yield of one non-Clearfield cultivar in 2015.

Stomp®Extra including 450 g/l Pendimethalin active ingredients generally increased plant height and stem diameter and decreased the number of days from planting to 50% flowering according to hoeing weed control.

Challenge600 including 600 g/l Aclonifen active ingredients generally caused increasing plant height and stem diameter according to hoeing weed control. In addition, this herbicide delayed flowering in P64LL05 cultivar in dry 2015.

Targa Super including 50 g/l Quizalofop-P-Ethyl active ingredients had also increases in plant height and stem diameter compared with hoeing weed control. This herbicide delayed flowering in P64LL05 although it decreased

the number of days from planting to 50% flowering in P64H34 hybrid especially dry growing season in 2015. Targa Super had higher seed oil content than hoeing weed control in P64LL05 in 2014.

Simic et al. (2011) found negative effects of imidazoline herbicides on seed yield and oil content in sunflower when the application is late. They found a positive effect of IMI herbicides on plant characters, unlike our research. Because there was no weed control in their control plots. Reddy et al. (2012) found negative effects of herbicides with pendimethalin active ingredients on seed yield components. There are many research results on the phytotoxic effects of herbicides on crops (Delchev, 2013; El-Rokiek et al., 2013)

Tichý et al. (2018) determined the negative effects of herbicides on seed yield components, especially under drought soil and climatic conditions. Renukaswamy et al. (2012) and Suryavanshi et al. (2015) found the highest yields in the herbicide-free plot. They indicated that herbicide applications had a negative effect on seed yield components. Results of previous research with IMI group herbicides are similar to our study results. But finding results with other herbicides applicated non-Clearfield cultivars in this study are quite different than previous studies.

The absence of herbicide residues in the seeds is a pleasing result. In this result, application time and dose are important. Increased herbicide doses can create pesticide residue in seeds (Serim and Maden, 2014).

The results showed that Intervix®Pro application on Clearfield cultivars causes stress on plant characters resulting in losses in seed yield, especially in drought conditions although it was not found statistically significant differences for seed yield in this research. Whereas positive effects of other herbicides applicated non-Clearfield hybrids on plant characters provide increases in seed yield except Targa Super application. This positive effect of herbicides on the seed yield even when their effects on weed control are not taken into account, could be statistically significant as BonoflanWG in drought conditions in this research unlike the results of previous studies. Although root measurements were not taken in this research, this is thought to be due to the fact that some herbicides encourage root development, and provide water and nutrient taking for a longer period of time in the generative period such as in cotton (Marple et al., 2007).

5. Conclusion

According to our results, there is no statistically significant difference in seed yield of cultivars between any Intervix® Pro herbicide application and mechanical hoeing weed control. On the other hand, this herbicide may be a negative effect on yield components such as plant height and stem diameter, especially in stress conditions such as drought. Unlike these herbicide results, pre-plant herbicide “Bonoflan” can have significantly positive effects on seed yield and yield components compared with mechanical weed control in low precipitation conditions. These results showed that producers need to be careful to avoid creating stress on plants. when applying IMI and other postemergence herbicides, especially in drought conditions. In these conditions, weed control by mechanical hoeing should come to the fore than herbicide application. The results showed that herbicides especially post-emergence applications under stress conditions can adversely affect agronomic yield and seed oil components in sunflower. Considering the damage caused by pesticides to the environment, herbicide application should be avoided when mechanical hoeing is economical or cost-effective.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Pattern of Agricultural Progress in India's North-East and the Contributing Factors: An Econometric Analysis

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Abstract

Despite being blessed with rich agro-climatic conditions, the largest agrarian state in India's North-East, Assam recorded relatively poor agricultural growth, since independence. The question of agricultural performance in terms of use of factors and growth pattern always arise that seems to vary in different stages of policy shift. Agricultural diversity increased in the initial phase with the expansion of agricultural area but slowed down in the later stages. However, the nature of agricultural diversity and use of resources including land allocations reflects the adaptation of farming community, absorption of labour force and sustainability of earning of farmers. The objectives are to analyze: i) the pattern of agricultural growth, diversity; ii) relative contribution of crop diversification, yield and area towards output growth in the pre-Green Revolution, Green Revolution and Post-Reform period; iii) association of various factors with crop yields in the short run and the adjustment process in the long run. Using secondary data, semi-log linear and spline regression functions we examined the growth and stationarity of growth processes is checked by ADF test. Times series analyses like cointegration and ARDL bound testing approach has been followed to examine the relation of various factors with yield of various crops in the short and long run. The ECM also provides the process of adjustment and CUSUM(Q) test is used for checking fitness of the models. Changes in diversity are analyzed through Herfindahl Index and the additive decomposition technique is employed to examine changing contribution of growth of yield, area and cropping pattern and their interactions. The result reveals varied impacts of main weather variable (rainfall), technological factors and cropping intensity on the yields of crops in different phases since 1950-51. Area effect on output and cropping pattern growth though declined, yield growth contributed increasingly in successive sub-periods in Assam. However, the contribution of modern technology towards the growth has not been uniform in the three major stages of agricultural transformation in Assam.

Keywords: Agricultural growth, Diversity, Agro-technology, Stationarity, Cointegration, ARDL Bound Test, North-East India.

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1. Introduction

1.1 Background

Agricultural progress is crucial for the economic development of several developing countries. Besides providing food, agriculture absorbs large labour force, thus provide income and employment to the rural masses. Development of agriculture in a region depends on agro-climatic specifications, socio-economic conditions of people, technical and institutional factors of that area. Existence of wide regional diversities and variations of the factors ultimately lead to uneven agricultural development across the region or country. Though the seed-water-fertilizer package (Green Revolution) was introduced in the mid-1960s to achieve self-sufficiency in food grains production, it was mainly confined to Punjab, Haryana and Western Uttar Pradesh. The Green Revolution technology gradually spread over the eastern parts of India during 1980s and the pace of adoption in North-East India has been very slow.

Assam is the largest agrarian state in North-East India, with varied agro-climatic endowments and agricultural diversity. Thus, varieties of food, non-food as well as horticultural crops are produced in this region depending upon the availability of various inputs, infrastructure and agro-implements. There are three distinct paddy growing seasons in the state viz., autumn, winter and summer paddy. Among these three seasonal varieties, winter paddy occupies the dominant position followed by summer paddy. Mustard is the most important non-food crop cultivated in winter. Also, maize, millets, tea, sugarcane, arecanut, banana are grown. Though over 70 percent of population of Assam relies on agriculture for livelihood, its contribution to Gross State Domestic Product (GSDP) has declined from 57.24 per cent in 1970-71 to 15.64 per cent in 2019-20 (Directorate of Economics and Statistics, Assam).

The state has not yet shown noticeable growth in use of modern technology in agriculture. About 47 per cent of area under paddy is covered by high yielding varieties (HYV) and merely about six per cent of gross area under cultivation (GCA) is covered by irrigation. Thus cropping intensity is pegged at low level (147.81 per cent). Per hectare fertilizer consumption is around 70 kg (Statistical Handbook of Assam, 2020).

A comparison with all India picture helps us to understand the prevailing agricultural status of Assam. While all India average cropping intensity increased from only 112 per cent in 1951-54 to 152 per cent in 2017-20; in Assam it increased from 106 per cent to 148 per cent during that period. Irrigation intensity at all India level increased from merely 17 per cent to about 50 per cent during last seven decades, in Assam still 6.43 per cent of GCA is covered under irrigation during 2017-20, although there are numerous Himalayan rivers and tributaries. It shows the underdeveloped status of irrigation prevailing in Assam. The rising cropping intensity whatever possible indicates that much of its increased area is without irrigation and at the mercy of rainfall. In terms of fertilizer consumption Assam was above all-India average with figures respectively 0.71 and 0.69 Kg per hectare in 1951-54, it increased to 70.34 Kg per hectare in Assam in comparison to phenomenal increase at all India level to 130.26 Kg per hectare in 2017-20. Also, coverage of HYV seeds in Assam is 47.53 per cent of GCA as against 57.49 per cent of all India average during 2017-20 (Govt. of India, Website: eands.dacnet.nic.in).

1.2 Objective

Agricultural growth is necessary not only for attaining high overall growth but also to address poverty. Understanding its nature of growth and contributing factors would help us to understand various issues related to agricultural growth and its change over time. Also, analysis of the nature of cropping pattern changes helps us to understand the nature of agricultural development and contribution of crop diversity towards agricultural growth. With this view in mind, this paper examines the growth of major crops (area, production and yield) and the use of various inputs associated with the production process.

Understanding the process of agricultural growth and application of factor inputs and technology would help in designing agricultural activities not only in India but also in other parts of the world depending on the regional agro-climatic conditions and available technical factors. Thus, the outcome of this paper would be of immense help in policy making for the farming community despite varied regional conditions.

The rest of the paper is organized as follows. In the next section a detailed review of literature is presented, which is followed by data and methodology and then the results with a detailed discussion. Finally, it ends up with concluding remarks.

1.3 Studies on Agricultural Development, Crop Diversity and Roles of Various Factors

Plethora of studies on agricultural development, crop diversity and the contributing factors are there and the relevant studies are reviewed here. Significant growth of area, production and yield of major crops in different parts of India over time has been observed in the studies of Bhalla and Singh (1997); Kalamkar, Atkare and Shende (2002). In general, variability of production has been more than the variability in area and yield during 1949-50 to 1997-98. High growths in production of foodgrains, cotton and sugarcane in the second half of 20th century were mainly due to yield effect. Contribution of growing cultivated area was seen for tur and oilseeds and area-yield interaction effect was recorded for wheat. Subrahmanyam and Sekhar (2003) found the annual growth of agriculture (total factor productivity) in Andhra Pradesh to be 3.5 per cent during 1955-56 to 1975-76 and it decelerated afterwards due to inadequate irrigation, changing agro-climatic conditions, limited investment in agricultural research. However, fertilizer application was recorded to be very high. Agriculture in Assam has also been subject to wide spatio-temporal variation with a slow process of adaptation and diversification to changing climate (De and Bodosa, 2015), but concentration of a few crops has been observed in case of West Bengal after 1980 due to commercialization and technological expansion (De and Chattopadhyay, 2010).

Although the economy of India has undergone structural transformation over time, with declining share of agriculture in GDP, dependence of rural workforce on agriculture for employment has not declined (Singh, 2010). Thus, pressure on agriculture is mounting to raise farmers' income. Changing cropping pattern revealed that after green revolution cultivation has been inclined to some high value non-food crops. The result of state-level analysis by Bhalla and Singh (2011) showed outstanding progress of labour productivity in the reform period with the adoption of new technology. It was however confined only to the irrigated areas. Diversification in favour of high value crops was observed, but during the post-reform period deceleration in rate of growth happened primarily for the decline in investment in irrigation or management of water resources. In some regions, it was due to decreasing input use efficiency and weather uncertainties (De, 2003). Like studies in other regions (De, 2000; De and Chattopadhyay, 2010; De and Bodosa, 2015), Kumar and Singh (2014) noted deceleration in area and production of sugarcane is observed in the state of Haryana, though yield growth was positive.

The decomposition analysis revealed that high growth rate in agriculture was due to cropping pattern shift towards high value crops (fruits, horticultural crops) and rising yield in Gujarat during 1990-2010 (Pattnaik and Shah, 2015). Crops exhibiting higher growth also show greater variability in yield and price. But the price effect of individual crops has increased over time with reduced yield effect. Price-area, price-yield interactions were stronger during 2000s as compared to 1990s. Substantial price increase is associated with favorable variation of area and yield during the 2000s when price effect was more important than the yield effect.

Zhai et al. (2017) examined the relationship among yield of wheat, use of machine, area under cultivation of wheat, fertilizer used, precipitation and temperature in Henan Province in China during 1970 to 2014. ARDL model was employed to test the influence of climatic factors as well as technical factors on yield of wheat in the long run. The climatic factors were found to have weak impacts on yield of wheat, while technical progress was primarily responsible for increasing yield of wheat. In the same way, Jena (2021) using Panel Autoregressive Distributed Lag (PARDL) model in selected districts of Odisha found adverse impacts of rising temperature and rainfall on the production of crops, which was similar to the findings of Chandio et al. (2019), and Guntukula and Goyari (2020). Using regression analysis, Reddy and Dutta (2018) found that pesticides, rainfall, electricity and use of HYV seeds have statistically significant impact on agricultural GDP but the impacts of fertilizer and net irrigated area were insignificant. Paria et al. (2021) revealed that greater irrigation facilities, diversified crop basket, use of more chemical fertilizers and higher yield positively affect cropping intensity. Moreover, rainfall variations and share of GSDP in agriculture have no significant impact on increasing cropping intensity.

2. Materials and Methods

2.1. Description of Data

The study is confined to the selected major crops (Paddy, Wheat, Tur, Mustard, Jute, Potato and Sugarcane) of Assam. The chosen crops are widely grown in the state and these crops together shares about 75 per cent of the total area under cultivation thus promp us to use for the purpose of analysis. Also, the selection of these crops is based on the availability of continuous data for the period 1951-52 to 2019-20. The entire study period is divided

into three sub-periods. Period I: Pre-Green Revolution (1951-54 to 1968-71), Period II: Green Revolution (1971-74 to 1988-91), and Period III: Economic Reforms (1991-94 to 2017-20). Although Green Revolution in India started in mid-1960s, it reached Assam in 1970s and very slowly. Thus, 1971 is considered here as the initial year of Green Revolution period in Assam. The decade of 1990s is well known for a series of economic reforms, including liberalization of agricultural market have taken place. The reasons to study those sub-periods are to examine if there has been any substantial change with the change in regime and economic policy adopted in the country and comparison of results of these sub-periods would provide an insight into the changes in sources of agricultural growth across different sub-periods.

The study is based on secondary data. Time series data on area, production and yield of the above-mentioned crops, gross cropped area (GCA), and rainfall are collected from Directorate of Economics and Statistics (DES), Government of Assam, Agriculture and Cooperation Department of Government of India for the period 1951-52 to 2019-20. Data on irrigation were available in the office of Chief Engineer, Irrigation Department of Assam since 1981-82. Area under high yielding varieties of crops in Assam was available since 1981-82 and that on fertilizer use was available from 1961-62 to 2019-20.

2.2 Methodology

Semi-log regression model is run to estimate the exponential growth rate of area, production, and yield. The regression equation used is $\text{Log } Y_t = \alpha + \beta t$ (Eq. 1),

where, Y_t represents value of dependent variable (area, production, or yield) at time 't', t is the time in year and α, β are the two parameters. Here, β is the annual exponential rate of growth of Y.

Besides, Poirier (1973) linear spline regression (Johnston, 1972) is employed to capture the trend effects of different periods. Considering linear trend, the regression equation for three different sub-periods assuming different slopes may be written as

$Y_t = \alpha_1 + \beta_1 t + u_t$ for $t \leq a$ (Eq. 2), where a = (1971-72)

$Y_t = \alpha_2 + \beta_2 t + u_t$ for $a < t \leq b$ (Eq. 3), where b = (1991-92)

$Y_t = \alpha_3 + \beta_3 t + u_t$ for $b < t$ (Eq. 4)

Combining all these equations (2, 3 and 4) with $\text{Ln}Y_t$, as dependent variable, it can be estimated together as

$\text{Ln } Y_t = \alpha_1 + \delta_1 D_{1t} + \delta_2 D_{2t} + \delta_3 D_{3t} + u_t$ (Eq. 5)

Where, $D_{1t} = t$ (for the period from 1951-52 till 1970-71)

$D_{2t} = 0$ for $t \leq a$ $D_{2t} = t - a$ for $a \leq t \leq b$ (for the period from 1971-72 to 1990-91)

$D_{3t} = 0$ for $t \leq a$ $D_{3t} = t - b$ for $a \leq t \leq b$ (for the period from 1991-92 to 2019-20)

Comparing equation set (2), (3) and (4) with equation (5), we find

$\beta_1 = \delta_1$

$\beta_2 = \delta_1 + \delta_2$ and

$\beta_3 = \delta_1 + \delta_2 + \delta_3$, which are nothing but the trend coefficients of the respective sub-periods.

After establishing the sub-period growth rates of area, production, and yield of selected crops all the variables have been checked for stationarity by using Augmented Dickey Fuller (Unit Root) Test with Schwarz Info Criterion (SIC) including intercept and time trend. It is checked for both the level and first difference form (Dickey and Fuller, 1979, 1981). Some of the variables are found to be stationary, which means integrated of order zero and others are integrated of order one. The test is done by using the following equation:

$\Delta Y_{it} = \alpha_i + \beta_i.t + \gamma_{i0} Y_{it-1} + \sum_j \delta_{ij} \Delta Y_{i, t-j} + \varepsilon_{it}$ (Eq. 6).

Here, Y_{it} is the value of respective dependent variable at time t. The inference is drawn based on the usual Dickey–Fuller τ- statistic of γ_{i0}, which has a non-standard distribution.

2.3 ARDL Model

Growth and diversity of agricultural crops is a continuous process influenced by several factors such as the use of physical inputs, irrigation, weather condition, market, access to credit, institutional and infrastructure development. Analyzing the effect of relevant variables within a simple framework is difficult as these variables affect crop output through various mechanisms. However, an attempt has been made to analyze the impact of irrigation, rainfall, chemical fertilizer and cropping intensity on output of the selected crops by estimating Autoregressive Distributed Lag (ARDL) model also known as bound testing cointegration technique as developed by Pesaran and Shin (1999), Pesaran et al. (2001). Since variables under consideration here are found to have different order of integration, ARDL model has been employed. Besides, it generates both the short run and long run coefficients simultaneously and follows the usual OLS procedure for cointegration among variables. Accordingly, the following general form of ARDL model with n lags for variable Y and m lag for variable X is specified as

$$Y_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i Y_{t-i} + \sum_{i=1}^{m} \beta_i X_{t-i} + U_t \quad \text{(Eq. 7)}$$

Whereas the general form of ARDL error correction model is as follows:

$$\Delta Y_t = \alpha_0 + \sum \beta_j Y_{t-i} + \sum \beta_j X_{t-j} + \varphi ECM_{t-i} + \varepsilon_t \quad \text{(Eq. 8)}$$

In the above equation, φ shows the speed of adjustment parameter and for significant ECM model φ must be negative. Error Correction Term specifies the short run adjustment of variables towards the long-run equilibrium. ECM_{t-1} is the residuals that are acquired from the estimated cointegration model.

The implicit relationship of yield of crop with variables is specified as follows:

Yield = f(Cultivated Area, Rainfall, Fertilizer Consumption, Irrigation, Cropping Intensity) (Eq. 9)

Here, irrigation and fertilizers capture the influence of technology, rainfall stands for changing climatic condition (significant proportion of cultivated area depend upon rainfall and its variation affects crop output substantially). Similarly, proxy for land (area under cultivation) is captured by cropping intensity as net sown area remains more or less constant over the years. This linear combination is transformed into log-linear model which would present suitable and proficient outcomes as compared to the simple linear model.

$$LnY_{it} = \beta_{i0} + \beta_{i1} LnA_{it} + \beta_{i2} LnRAIN_t + \beta_{i3} LnFER_t + \beta_{i4} LnIRRI_t + \beta_{i5} LnCI_t + \mu_{it} \quad \text{(Eq. 10)}$$

Where, Y_{it} represents the yield of i^{th} agricultural crop, A_{it} represents area under i^{th} crop, while $RAIN_t$, FER_t, $IRRI_t$ and CRI_t represent rainfall, consumption of fertilizer, irrigation and cropping intensity respectively.

The ARDL model has two steps for estimation. In the first step, we examine the presence of a long-run relationship between the agricultural crops and study inputs by using the model.

$$\Delta LnY_{it} = \alpha_0 + \sum_{j=1}^{p} \alpha_{1ij} \Delta LnY_{it-k} + \sum_{j=1}^{p} \alpha_{2ij} \Delta LnA_{it-k} + \sum_{j=1}^{p} \alpha_{3ij} \Delta LnRAIN_{t-k} + \sum_{j=1}^{p} \alpha_{4ij} \Delta LnFER_{t-k} + \sum_{j=1}^{p} \alpha_{5ij} \Delta LnIRRI_{t-k} + \sum_{j=1}^{p} \alpha_{6ij} \Delta LnCI_{t-k} + \beta_{1i} LnY_{it-1} + \beta_{2i} LnA_{it-1} + \beta_{3i} LnRAIN_{t-1} + \beta_{4i} LnFER_{t-1} + \beta_{5i} LnIRRI_{t-1} + \beta_{6i} LnCI_{t-1} + \varepsilon_{it} \quad \text{(Eq. 11)}$$

In the second step, we estimate the short-run relation among the study variables using the error Correction Model (ECM), which is written as

$$\Delta LnY_{it} = \alpha_0 + \sum_{j=1}^{p} \alpha_{1ij} \Delta LnY_{it-k} + \sum_{j=1}^{p} \alpha_{2ij} \Delta LnA_{it-k} + \sum_{j=1}^{p} \alpha_{3ij} \Delta LnRAIN_{t-k} + \sum_{j=1}^{p} \alpha_{4ij} \Delta LnFER_{t-k} + \sum_{j=1}^{p} \alpha_{5ij} \Delta LnIRRI_{t-k} + \sum_{j=1}^{p} \alpha_{6ij} \Delta LnCI_{t-k} + \varphi ECM_{it-1} + \varepsilon_{it} \quad \text{(Eq. 12)}$$

2.4 Bound Testing Procedure

In ARDL Bound testing, long-run relationship among the variables is checked. At first, cointegration among the variables is checked. The null hypothesis that H_0: $\beta_{ji} = 0$, for all j = 1, 2, …, 6 indicates the absence of any cointegration among yield, area under crop, rainfall, consumption of fertilizer, irrigation and cropping intensity.

Wald F-statistic is used to check the significance of lagged levels of the variables in a conditional unrestricted equilibrium error correction model. The test includes the F-test of the joint significance of the coefficient of lagged variables to verify that there is a long-term relation among the variables. Pesaran et al. (2001) has provided one upper and a lower critical value for testing. If the computed value of F-statistic is greater than upper critical bound, then the H_0 is rejected, and the variables are considered to be co-integrated. On the other hand, if the value of F-statistic is lower than the lower critical bound (LCB), then the variables are not co-integrated. However, if value of F-statistic falls within the lower and upper critical values band then inference of inconclusive test is drawn. Akaike Information Criterion (AIC) is used for appropriate lag selection. At this stage, the long run elasticities β_{1i}, β_{2i}, β_{3i}, β_{4i}, β_{5i}, and β_{6i} are obtained.

2.5 CUSUM and CUSUMQ Test

After confirming long-run relationship among the variables, we incorporate cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ) tests (Brown et al., 1975). These tests are used to check the goodness of fit for ARDL model as suggested by Pesaran et al. (2001) to incorporate the residuals of the error correction model and the results are presented in graphical form. For existence of the stability the plot of CUSUM and CUSUMQ have to lie within the 5% critical band.

2.6 Diversification of Crop and its Contribution to Agricultural Growth

For simplicity and its wide application, Herfindahl Index (HI) of diversification is used for measuring crop diversity and its variation over time. Mathematically, the index $HI = \sum(P_i)^2$ (Eq. 13) where, P_i represents acreage proportion of i^{th} crop in total cropped area. The value of the index ranges between 0 and 1 and a higher value of HI implies less diversification i.e., more concentration and vice-versa. On the other hand, the Simpson Index (SI) measures the extent of diversity and is written as $SI = 1 - \sum p_i^{\,2}$, where p_i represents proportion of area under i^{th} crop to GCA. A zero value means that the total cultivated area is dedicated to a single crop (perfect specialization) and if the area is evenly distributed among all the crops (i.e., maximum diversification), it approaches to one.

The additive decomposition of agricultural growth (Minhas and Vaidyanathan, 1965) has been used to examine the relative contribution of area, yield, cropping pattern and their interactions to total change in output. It has been worked out as follows:

Changes in output during a period $\Delta Q = Q_t - Q_0 = A_t \sum C_{it} Y_{it} P_{i0} - A_0 \sum C_{i0} Y_{i0} P_{i0,}$

$= (A_t - A_0) \sum C_{i0} Y_{i0} P_{i0} + A_0 \sum C_{i0} (Y_{it} - Y_{i0}) P_{i0} + A_0 \sum (C_{it} - C_{i0}) Y_{i0} P_{i0} + (A_t - A_0) \sum (C_{it} - C_{i0}) Y_{i0} P_{i0}$

$+ (A_t - A_0) \sum C_{i0} (Y_{it} - Y_{i0}) P_{i0} + A_0 \sum (C_{it} - C_{i0})(Y_{it} - Y_{i0}) P_{i0} + (A_t - A_0) \sum (C_{it} - C_{i0})(Y_{it} - Y_{i0}) P_{i0}$ (Eq. 14)

Where, Q_0 and Q_t represent total value of agricultural output at constant price (P_{i0}) of the region in the base and final period respectively. A_0 and A_t are GCA in the base and final period respectively. $C_{i0} = (A_{i0}/A_0)$ and $C_{it} = (A_{it}/A_0)$ are respectively the proportion of area under i^{th} crop to GCA in the base and final period and Y_{it} and Y_{i0} represent yield of i^{th} crop in the base and final period, P_{io} is the harvest price of i^{th} crop in the base period (here 1951-52). On the right-hand side of equation (14), the first three components represent direct effects of area, yield and cropping pattern, which means the change in output due to variation of single factor only keeping the other two factors constant. The next three components are the interaction effects of area-cropping pattern, area-yield, and cropping pattern-yield. The last one is the interaction of all i.e., area, yield and cropping pattern.

3. Results and Discussion

3.1 Agricultural Growth

Substantial growth in area and production of major crops has been recorded during the first two sub-periods i.e., 1951-54 to 1970-73 and 1971-74 to 1990-93. Whereas, during the reform period (1991-94 to 2017-20), a significant diversity towards a few crops has been observed (*Table 1*). Yield of major crops also grew faster during the Green Revolution period and that continued in the third period, excepting wheat, tur, jute and sugarcane. Growth rate of area and production of autumn paddy have been positive but decelerated in the later period and became negative during Period III. Although positive area and production growth rate of autumn paddy was not associated with yield growth (which was negative) in the Period I, its yield attained accelerated growth in periods

II and III. Increase in production of winter paddy during Periods I and II was due to the expansion of cultivated area. However, during period III growth rate of production declined despite acceleration in yield growth. Production growth rate of summer paddy was the highest at 11.62 per cent annual exponential rate during Period I, which decelerated in Period II and increased further during Period III. Increase in production was the result of increase in area and yield of summer paddy during all the sub-periods.

Table 1. Annual Exponential Rate of Growth of Area, Production and Yield of Major Crops in Assam (1951-54 to 2017-20) (per cent)

	Area			***Production***			***Yield***		
Crops	*Period I*	*Period II*	*Period III*	*Period I*	*Period II*	*Period III*	*Period I*	*Period II*	*Period III*
Autumn Paddy	2.52***	0.41*	-5.74***	1.98***	0.88	-3.72***	-0.53	0.47	2.14***
Winter Paddy	0.90***	1.07***	0.31***	0.97***	2.18***	1.96***	0.07	1.10***	1.64***
Summer Paddy	11.51***	4.27***	4.45***	11.62***	4.46***	6.92***	0.10	0.18	2.36***
Total Paddy	1.36***	0.98***	-0.16*	1.23***	2.03***	2.06***	-0.13	1.04***	2.23***
Wheat	9.08***	5.28***	-6.29***	8.90***	4.69***	-5.98***	-0.17	-0.56*	0.33
Tur	0.89	3.10***	-0.68***	3.05***	2.92***	0.43**	2.14**	-0.18	1.11***
Rape & Mustard	0.98***	5.50***	-0.13	0.64	6.38***	0.96**	-0.33	0.83*	1.10***
Jute	0.30***	-1.28***	-1.19***	0.45	-0.13	-0.45	0.15	1.16**	0.75***
Potato	1.97***	5.39***	1.78***	0.35	8.56***	1.46***	-1.58	3.00***	-0.31
Sugarcane	1.44***	0.61	-0.62**	3.68***	11.31***	-0.77**	2.21***	10.63***	-0.15

Note: ***, ** and * indicates significant level of 1%, 5% and 10% respectively

Growth rate of production of wheat was significantly positive during Periods I and II, which however became significantly negative during Period III. Area of wheat also followed a similar pattern; yield growth has been insignificant throughout the study periods. Growth rates of area and production of tur has declined during the period III though it was positive in the initial years and the yield growth rate declined continuously till the Period III. Production of mustard also saw accelerated growth from first to second sub-period and declined again during Period III. The increase in production in earlier Green Revolution period was due to growth of area under cultivation, which was however negative during Period III. The yield growth however followed a continuous upward trend. Jute and sugarcane saw declining trend in area and production with the progress of agriculture despite some increase in its yield. The growth rate of production for potato was positive over all the periods, alongside the area and yield, particularly in Periods II and III.

Table 2. Annual Exponential Rate of Growth during different Sub-periods Obtained from the Estimation of Spline Function (per cent)

	Area			***Production***			***Yield***		
Crops	*Period I*	*Period II*	*Period III*	*Period I*	*Period II*	*Period III*	*Period I*	*Period II*	*Period III*
Autumn Paddy	2.56***	-1.72***	-8.14***	2.66 ***	-1.81***	-6.10***	0.09	-0.09	2.22***
Winter Paddy	0.92***	0.29***	-0.62***	1.58***	0.30	0.51	0.66***	0.01	1.14***
Summer Paddy	9.44***	-4.20***	-4.93***	10.63***	-4.83***	-3.61***	1.08***	-0.66	1.39***
Total Paddy	1.34***	-0.13	-1.52***	1.89***	-0.13	0.32	0.54***	-0.01	1.87***
Wheat	12.35***	1.89	-17.23***	14.21***	2.25***	-18.37***	1.66***	0.35	-1.39**
Tur	2.77***	2.18***	-3.33***	3.01***	2.35***	-2.87***	0.23	0.18	0.47
Rape & Mustard	2.52***	1.36***	-2.12***	2.86***	1.65**	-1.23**	0.33**	0.29	0.91**
Jute	-1.04***	0.49	-0.48	-0.40*	0.36	-0.20	0.65***	-0.13	0.28
Potato	3.31***	-0.10	-0.96***	5.03***	-0.21**	-2.15**	1.67***	-0.11	-1.20*
Sugarcane	0.73***	2.00***	-1.77**	8.20***	-3.55***	-6.73***	7.41***	-5.44***	-5.05***

Note: ***, ** and * indicates significant level of 1%, 5% and 10% respectively

During Period I, stable and positive production growth rate of major crops was mainly due to increase in area for all the crops except for tur and sugarcane (*Table 1*). It may be noted that during Period I there was very little modernization of agriculture in Assam, as reflected from inadequate usage of fertilizer, negligible irrigation and lack of technological innovation. Area growth continued to be positive during Period II except for jute. However, increase in area growth rate was more in case of tur, mustard and potato, which indicates accelerated pace of diversification for non-food crops during that period. Growth rates of production were also observed to be positive and stable for most of the crops and yield growth also improved except for wheat and tur. Period II, the phase of

Green Revolution in Assam, recorded faster growth of yield with the gradual adoption of modern techniques. During Period III, growth rates of area and production were negative for most of the crops, as land size was inelastic and land use for other purposes also grew. But positive growth of yields of most of the crops has been recorded for the growing usage of fertilizer, irrigation and certain modern implements. Summer paddy also managed to maintain a significant positive growth throughout the periods.

Table 3. Unit Root Test for Stationarity of Log of Area and Yield of Major Crops, Rainfall, Irrigation, Fertilizer and Cropping Intensity during 1951 to 2019

Variable	*Level*	*First Difference*	*Order of Integration*	*Variable*	*Level*	*First Difference*	*Order of Integration*
LnAAP	2.82 (1.00)	-10.16 (0.00)	I(1)	LnYAP	-2.01 (0.5833)	-8.70 (0.00)	I(1)
LnAWP	-1.80 (0.695)	-11.52 (0.00)	I(1)	LnYWP	-3.96 (0.0148)	-12.55 (0.0001)	I(0)
LnASP	-2.86 (0.177)	-8.78 (0.00)	I(1)	LnYSP	-3.37 (0.0662)	-10.24 (0.00)	I(0)
LnATP	-1.16 (0.910)	-10.09 (0.00)	I(1)	LnYTP	-1.71 (0.7364)	-5.07 (0.0006)	I(1)
LnAWT	0.30 (0.998)	-8.00 (0.00)	I(1)	LnYWT	-3.73 (0.0269)	-9.90 (0.00)	I(0)
LnATR	-1.65 (0.763)	-9.50 (0.00)	I(1)	LnYTR	-6.01 (0.00)	-9.52 (0.00)	I(0)
LnARM	-0.947 (0.944)	-7.765 (0.00)	I(1)	LnYRM	-5.49 (0.0001)	-12.14 (0.00)	I(0)
LnAJT	-3.43 (0.057)	-10.65 (0.00)	I(0)	LnYJT	-6.95 (0.00)	-14.84 (0.00)	I(0)
LnAPT	-1.87 (0.662)	-10.42 (0.00)	I(1)	LnYPT	-4.56 (0.0026)	-12.70 (0.0001)	I(0)
LnASG	0.25 (0.756)	-2.68 (0.0081)	I(1)	LnYSG	-2.43 (0.3610)	-9.90 (0.00)	I(1)
LnRAIN	-1.64 (0.766)	-8.02 (0.00)	I(1)	LnFER	-1.73 (0.7288)	-10.11 (0.00)	I(1)
LnIRRI	-1.89 (0.649)	-8.10 (0.00)	I(1)	LnCRI	-1.64 (0.7657)	-8.15 (0.00)	I(0)

Critical Value: 1% (-4.10), 5% (-3.48), 10% (-3.17)

Note: *AAP, AWP, ASP, ATP, AWT, ATR, ARM, AJT, APT, ASG indicate – area under autumn paddy, winter paddy, summer paddy, total paddy, wheat, tur, mustard, jute, potato and sugarcane respectively. Similarly, YAP, YWP, YSP, YTP, YWT, YTR, YRM, YJT, YPT, YSG represent yield of autumn paddy, winter paddy, summer paddy, total paddy, wheat, tur, mustard, jute, potato and sugarcane respectively. Also, RAIN, IRRI, FER, CRI represent rainfall, irrigation, fertiliser and cropping intensity.*

More or less a similar picture is observed in the growth of area, production and yield during various sub-periods from the result of linear spline regression model (*Table 2*). Only, there was very high growth of area and yield of summer paddy that resulted in significant production growth during Period I. However, during Period II, decline in yield was observed and it bounced back during Period III. In case of total paddy, annual exponential growth rate of area under cultivation and production decelerated, while yield growth recorded an accelerated trend from Period I to Period III. During Period I, there were marked growth in production of all the crops except jute and it was the result of both area and yield growth. But, during Period II, trends of production, area and yield of autumn and summer paddy, potato and sugarcane were negative. During Period III, improvement in yield was observed for wheat, potato and sugarcane as compared to the previous period. In general, there has been a decelerating trend in area of several crops over the periods except for a few crops. However, growth rate of yield improved for most of the crops due to better application of modern agricultural inputs and implements.

3.2 Unit Root Test Results

Bound testing approach is necessitated for all the variables to be integrated of I(0) or I(1) or of both nature but not integrated of I(2) for the computation of F-statistics. In order to find the order of integration, Augmented

Dickey Fuller test is employed. The results reveal that log of area under all the crops are I(1) except area under jute, which is stationary (*Table 3*). On the other hand, log of yield of winter and summer paddy, wheat, mustard, jute, potato and cropping intensity are stationary (i.e., I(0)) while, the other variables including log of yields of other crops, rainfall, irrigation, fertilizer are non-stationary (i.e. I(1)).

3.3 Lag Selection Criteria and ARDL Bound Test Cointegration

Before applying ARDL bound test to check for any cointegration among yield of a crop, area under crop, rainfall, use of fertilizer, irrigation and cropping intensity; it is necessary to select an appropriate lag order of the variable. The optimal ARDL model for the dependent variables has been chosen based on the Akaike Information Criterion, which is presented in Table 4. It is observed that lag 1 is the best fit for the chosen sample size. Also, the findings of cointegration test on the basis of ARDL bound testing approach are displayed in *Table 4*. The F-statistics are greater than upper bound values at 1% level of significance for the dependent variables LnYAP, LnYWP, LnYSP, LnYTR, LnYRM, LnYJT, LnYPT and LnYWT, which confirms the presence of long run relationship among the variables under consideration. In case of dependent variables LnYTP and LnYSG, the computed value of F-statistics falls below the lower bound values and thus the null hypothesis of no cointegration cannot be rejected. Even if there is no cointegration, one may estimate the short run relationship between the variables under consideration but not the long run one.

Table 4. ARDL Cointegration Bound Test Results

Dependent Variables	***Optimal Lag Structure***	***F-Statistics***
LnYAP	(1,0,0,1,1,0)	7.462054***
LnYWP	(1,0,0,0,0,1)	4.796705***
LnYSP	(1,3,2,1,0,1)	5.075069***
LnYTP	(1,1,1,0,1,0)	1.947115
LnYWT	(1,0,0,0,0,1)	4.683062**
LnYTR	(1,1,0,0,0,0)	6.397678***
LnYRM	(1,0,1,0,0,1)	5.984123***
LnYJT	(1,0,0,0,0,0)	9.024761***
LnYPT	(1,1,0,1,0,0)	5.813036***
LnYSG	(1,0,0,0,0,0)	2.213922
Critical Values (%): 1	5	10
Lower Bound *I(0)*: 3.41	2.62	2.26
Upper Bound *I(1)*: 4.68	3.79	3.35

***Note*:** *** and ** indicate significance at 1% and 5% level respectively.

3.4 Long Run and Short Run Analysis

Table 5 presents the short-run and long-run coefficients estimated by using ARDL Model (Eq. 11). For yield of autumn paddy, none of the short-run coefficients is found to be statistically significant. But the long run coefficients of lagged yield of autumn paddy and its area under cultivation is statistically significant. In the long run, negative coefficient of area under autumn paddy indicates inverse relationship between yield and area. For yield of winter paddy, both the short and long run coefficients of area under cultivation are positive, while rainfall has significant positive relation in the long run, but it adversely affects in the short run. Cropping intensity is found to have negative relationship with yield of winter paddy in the short run, though it is positively related in the long run. These results suggest the long run positive association for the growing application of fertilizer.

In case of yield of summer paddy, the area under cultivation and rainfall has significant positive association. In the short run, most of the variables have significant inverse association; while in the long run, area under cultivation, rainfall, fertilizer, irrigation and cropping intensity have significant positive relation. The coefficient of consumption of fertilizer and cropping intensity are positive in case of yield of summer paddy, indicating the intensive practice of it with the passage of time. The result further reveals that for 1% increase in consumption of fertilizer, yield of paddy overall is increased by 0.12%.

In case of wheat, cropping intensity has significant short-run negative association with yield. For each 1% increase in cropping intensity, overall yield of wheat is decreased by 0.06%. In case of yield of jute, irrigation has significant positive association in the long run. In this case, for 1% increase in irrigation facility caused increase in yield of jute by 0.0113%. As cultivation of jute is dependent on warm and wet climate, availability of irrigation

facility helps to increase yield of jute. In case of yield of tur, in the short run rainfall and irrigation are found to have positive association while area has negative association. Area under cultivation cannot be increased as cultivation of tur coincides with the timing of winter paddy in Assam (June-July). Rainfall and irrigation facility boost tur production in the short run. Whereas in the long run, rainfall and irrigation have negative association with yield; but fertilizer and cropping intensity have significant positive association.

Table 5. Results of ARDL Models Exhibiting Short- and Long Run Coefficients

Variables	*Coefficient*	*t-Statistic*	*Variables*	*Coefficient*	*t-Statistic*
Dependent Variable: D(LnYAP)			***Dependent Variable: D(LnYWP)***		
C	8.4681***	3.7107 (0.0005)	C	0.9608	0.2774 (0.7826)
D(LnYAP(-1))	-0.1438	-0.9275 (0.3582)	D(LnYWP(-1))	-0.2375*	-1.7534 (0.0858)
D(LnAAP)	-0.1555	-0.3858 (0.7013)	D(LnAWP)	0.4848*	1.7130 (0.0930)
D(LnAAP(-1))	-0.0182	-0.0439 (0.9651)	D(LnAWP(-1))	0.5507*	1.9413 (0.0580)
D(LnRAIN)	0.0049	0.2487 (0.8046)	D(LnRAIN)	-0.0073	-0.7997 (0.4277)
D(LnRAIN(-1))	0.0681	0.3731 (0.7106)	D(LnRAIN(-1))	0.2149**	2.6110 (0.0119)
D(LnFER)	0.1689	1.2422 (0.2201)	D(LnFER)	0.0778	1.2444 (0.2193)
D(LnFER(-1)	-0.0604	-0.4210 (0.6756)	D(LnFER(-1)	-0.1048	-1.5044 (0.1389)
D(LnIRRI)	-0.0075	-0.5801 (0.5645)	D(LnIRRI)	-0.0004	-0.0754 (0.9402)
D(LnIRRI(-1))	0.0011	0.0930 (0.9263)	D(LnIRRI(-1))	0.0076	1.3704 (0.1768)
D(LnCRI)	0.1112	0.4192 (0.6768)	D(LnCRI)	0.0142	0.1166 (0.9076)
D(LnCRI(-1))	-0.0041	-0.1278 (0.8988)	D(LnCRI(-1))	-0.0293*	-1.9528 (0.0566)
LnYAP(-1)	-0.7187***	-3.6599 (0.0006)	LnYWP(-1)	-0.3798***	-2.8037 (0.0072)
LnAAP(-1)	-0.3000***	-3.0869 (0.0033)	LnAWP(-1)	0.0965	0.3628 (0.7182)
LnRAIN(-1)	-0.1262	-0.6512 (0.5179)	LnRAIN(-1)	-0.2154**	-2.4595 (0.0175)
LnFER(-1)	0.0167	0.5133 (0.6100)	LnLnFER(-1)	0.0399**	2.3460 (0.0231)
LnIRRI(-1)	0.0049	0.6653 (0.5090)	LnIRRI(-1)	-0.0026	-0.7500 (0.4568)
LnCRI(-1)	0.2182	0.6941 (0.4909)	LnCRI(-1)	0.3407**	2.3499 (0.0228)
Dependent Variable: D(LnYSP)			***Dependent Variable: D(LnYWT)***		
C	2.6708***	3.8898 (0.0003)	C	3.2792***	3.4182 (0.0013)
D(LnYSP(-1))	-0.1840	-1.2932 (0.2020)	D(LnYWT(-1))	-0.0102	-0.0757 (0.9399)
D(LnASP)	-0.0270	-0.2803 (0.7804)	D(LnAWT)	-0.0847	-0.8080 (0.4230)
DLn (ASP(-1))	0.2386**	2.6004 (0.0123)	D(LnAWT(-1))	0.0493	0.5198 (0.6055)
D(LnRAIN)	-0.0055	-0.2938 (0.7701)	D(LnRAIN)	-0.0064	-0.3255 (0.7462)
D(LnRAIN(-1))	0.2856*	1.7954 (0.0788)	D(LnRAIN(-1))	0.2189	1.2314 (0.2240)
D(LnFER)	0.1807	1.3192 (0.1932)	D(LnFER)	0.0908	0.6573 (0.5141)
D(LnFER(-1)	0.0437	0.3326 (0.7409)	D(LnFER(-1)	0.0949	0.6366 (0.5273)
D(LnIRRI)	-0.0070	-0.6059 (0.5474)	D(LnIRRI)	-0.0079	-0.6138 (0.5421)
D(LnIRRI(-1))	0.0063	0.5644 (0.5750)	D(LnIRRI(-1))	0.0069	0.5601 (0.5779)
D(LnCRI)	0.1790	0.7607 (0.4505)	D(LnCRI)	-0.1264	-0.4743 (0.6373)
D(LnCRI(-1))	-0.0155	-0.5377 (0.4505)	D(LnCRI(-1))	-0.0641*	-1.7074 (0.0941)
LnYSP(-1)	-0.3839***	-3.2991 (0.0018)	LnYWT(-1)	-0.5776***	-4.0631 (0.0002)
LnASP(-1)	-0.2017**	-2.0437 (0.0464)	LnAWT(-1)	0.0296	0.6629 (0.5105)
LnRAIN(-1)	-0.3913**	-2.4899 (0.0162)	LnRAIN(-1)	-0.1568	-0.9141 (0.3651)
LnFER(-1)	0.2325***	3.0067 (0.0042)	LnFER(-1)	0.0279	1.0221 (0.31180
LnIRRI(-1)	-0.0168**	-2.4926 (0.0161)	LnIRRI(-1)	-0.0106	-1.2688 (0.2105)
LnCRI(-1)	0.6539**	2.5502 (0.0139)	LnCRI(-1)	0.3003	1.0945 (0.2791)

Table 5. (continuance).

Dependent Variable: D(LnYJT)			***Dependent Variable: D(LnYTR)***		
C	5.4109**	2.0454 (0.0462)	C	5.4762***	5.8885 (0.0000)
D(LnYJT(-1))	-0.1052	-0.7283 (0.4698)	D(LnYTR(-1))	-0.0019	-0.0269 (0.9786)
D(LnAJT)	0.1727	0.8890 (0.3783)	D(LnATR)	-0.2331***	-3.2510 (0.0021)
D(LnAJT(-1))	0.0237	0.1305 (0.8976)	D(LnATR(-1))	-0.0849	-1.2263 (0.2259)
D(LnRAIN)	-0.0038	-0.2288 (0.8200)	D(LnRAI)	-0.0030	-0.3285 (0.7439)
D(LnRAIN(-1))	0.0708	0.4713 (0.6395)	D(LnRAIN(-1))	0.2572***	3.1354 (0.0029)
D(LnFER)	0.0179	0.1587 (0.8745)	D(LnFER)	-0.0708	-1.0833 (0.2840)
D(LnFER(-1)	-0.1258	-1.0903 (0.2809)	D(LnFER(-1)	-0.0666	-0.9693 (0.3371)
D(LnIRRI)	0.0155	1.4866 (0.1435)	D(LnIRRI)	0.0033	0.5471 (0.5868)
D(LnIRRI(-1))	-0.0045	-0.4396 (0.6621)	D(LnIRRI(-1))	0.0128**	2.1004 (0.0409)
D(LnCRI)	-0.2019	-0.8780 (0.3842)	D(LnCRI)	0.0525	0.4320 (0.6676)
D(LnCRI(-1))	0.0376	1.3418 (0.1858)	D(LnCRI(-1))	-0.0041	-0.2558 (0.7992)
LnYJT(-1)	-0.8124***	-4.2045 (0.0001)	LnYTR(-1)	-0.9109***	-12.234 (0.0000)
LnAJT(-1)	0.0001	0.0010 (0.9991)	LnATR(-1)	0.0218	0.2828 (0.7785)
LnRAIN(-1)	0.0604	0.4108 (0.6830)	LnRAIN(-1)	-0.2837***	-3.6058 (0.0007)
LnFER(-1)	0.0540	1.3323 (0.1889)	LnFER(-1)	0.0412***	2.8949 (0.0056)
LnIRRI(-1)	0.0113*	1.8584 (0.0691)	LnIRRI(-1)	-0.0144***	-2.8385 (0.0066)
LnCRI(-1)	-0.1108	-0.4597 (0.6477)	LnCRI(-1)	0.4493***	3.5421 (0.0009)
Dependent Variable: D(LnYRM)			***Dependent Variable: D(LnYPO)***		
C	1.3817	0.5084 (0.6134)	C	4.6118	1.5119 (0.1370)
D(LnYRM(-1))	-0.1971	-1.4302 (0.1590)	D(LnYPO(-1))	-0.2125	-1.4571 (0.1515)
D(LnARM)	0.2678	0.8009 (0.4270)	D(LnAPO)	0.8399*	2.0022 (0.0508)
D(LnARM(-1))	-0.0137	-0.0496 (0.9606)	D(LnAPO(-1))	-0.3767	-0.7765 (0.4411)
D(LnRAIN)	-0.0014	-0.0973 (0.9228)	D(LnRAI)	0.0336	1.1679 (0.2485)
D(LnRAIN(-1))	0.1537	1.0793 (0.2857)	D(LnRAIN(-1))	0.1903	0.7926 (0.4318)
D(LnFER)	0.1028	0.9302 (0.3568)	D(LnFER)	0.2187	1.2009 (0.2355)
D(LnFER(-1)	0.0498	0.3988 (0.6917)	D(LnFER(-1)	0.1421	0.7817 (0.4381)
D(LnIRRI)	-0.0100	-0.8490 (0.4000)	D(LnIRRI)	0.0160	0.9467 (0.3484)
D(LnIRRI(-1))	0.0070	0.5618 (0.5768)	D(LnIRRI(-1))	-0.0069	-0.4290 (0.6698)
D(LnCRI)	0.1447	0.6736 (0.5037)	D(LnCRI)	0.1565	0.4308 (0.6684)
D(LnCRI(-1))	-0.0243	-0.8531 (0.3977)	D(LnCRI(-1))	-0.0705*	-1.6977 (0.0959)
LnYRM(-1)	-0.5169***	-3.1367 (0.0029)	LnYPO(-1)	-0.5214***	-3.3199 (0.0017)
LnARM(-1)	0.1220	0.5376 (0.5933)	LnAPO(-1)	-0.0255	-0.0795 (0.9369)
LnRAIN(-1)	-0.2881**	-2.0239 (0.0484)	LnRAIN(-1)	-0.2677	-1.0893 (0.2813)
LnFER(-1)	0.0391	1.6363 (0.1082)	LnFER(-1)	0.0052	0.0725 (0.9425)
LnIRRI(-1)	-0.0134	-1.0076 (0.3186)	LnIRRI(-1)	0.0096	0.7100 (0.4810)
LnCRI(-1)	0.4560*	1.9276 (0.0597)	LnCRI(-1)	0.4635	1.1528 (0.2546)
Dependent Variable: D(LnYTP)			***Dependent Variable: D(LnYSG)***		
C	0.0081	0.7707 (0.4441)	C	0.0676	1.0211 (0.3117)
D(LnYTP(-1))	-0.4305***	-3.3675 (0.0014)	D(LnYSG(-1))	-0.2432*	-1.8680 (0.0671)
D(LnATP)	0.4936*	1.7520 (0.0853)	D(LnASG)	-1.0649	-1.1841 (0.2415)
D(LnATP(-1))	0.3612	1.2608 (0.2127)	D(LnASG(-1))	-1.7276*	-1.9538 (0.0558)
D(LnRAIN)	-0.0020	-0.2377 (0.8129)	D(LnRAI)	0.0199	0.4213 (0.6751)
D(LnRAIN(-1))	0.0311	0.4786 (0.6341)	D(LnRAIN(-1))	0.0009	0.0025 (0.9980)
D(LnFER)	0.1180**	2.0270 (0.0475)	D(LnFER)	-0.2333	-0.6233 (0.5357)
D(LnFER(-1)	-0.0605	-0.9652 (0.3386)	D(LnFER(-1)	-0.0342	-0.0879 (0.9303)
D(LnIRRI)	-0.0015	-0.2674 (0.7901)	D(LnIRRI)	0.0152	0.5012 (0.6182)
D(LnIRRI(-1))	0.0046	0.8610 (0.3930)	D(LnIRRI(-1))	0.0087	0.2971 (0.7675)
D(LnCRI)	-0.0356	-0.3425 (0.7332)	D(LnCRI)	0.0012	0.0020 (0.9984)
D(LnCRI(-1))	-0.0213	-1.5729 (0.1215)	D(LnCRI(-1))	0.0596	0.7715 (0.4437)

Notes: (1) ***, ** and * indicates significant levels at 1%, 5% and 10% respectively.
(2) Figures in parentheses indicate probability value.

In case of yield of mustard, none of the short run coefficients, is statistically significant. The cointegrating coefficient of rainfall is significantly negative, while that of cropping intensity is positive. Further, in the short run area under cultivation has significant positive association with the yield of potato and cropping intensity has significant negative association with it. In the long run, lagged value of yield itself has significant negative

association and none of the other variables are found to be statistically significant. For yield of sugarcane, only area has been found to have negative association in the short run.

3.5 ARDL-Error Correction Model

The results of the error correction model reveal that for yield of all the crops, coefficients of ECM terms are negative and significant (*Table 6*). The error correction term is less than 1 and significant, indicating the short run adjustment for any shock towards long run equilibrium. The higher values of ECM show relatively faster adjustment process for any short-run deviation from long run equilibrium, which is found in case of tur, jute, autumn paddy (the so-called inferior crops (De & Bodosa, 2015)) as compared to that of summer paddy, potato, mustard. Whereas, the oefficients of other variables have expected sign but not significant in most of the cases due to their poor growth like irrigation, chemical fertiliser etc as observed before.

Table 6. Results of Estimated Error Correction Model

Variables	*Coefficient*	*t-Statistic*	*Variables*	*Coefficient*	*t-Statistic*
Dependent Variables: D(LnYAP)			***Dependent Variables: D(LnYWP)***		
C	0.0023	0.1019 (0.9191)	C	0.0048	0.4383 (0.6629)
D(LnYAP(-1))	-0.1586	-1.1148 (0.2698)	D(LnYWP(-1))	-0.2486*	-1.8487 (0.0700)
D(LnAAP)	-0.2428	-0.8964 (0.3740)	D(LnAWP)	0.6493**	2.4890 (0.0159)
D(LnAAP(-1))	-0.1334	-0.4888 (0.6269)	D(LnAWP(-1))	0.5532**	2.0440 (0.0458)
D(LnRAIN)	0.0042	0.2295 (0.8193)	D(LnRAIN)	-0.0097	-1.1019 (0.2754)
D(LnRAIN(-1))	0.0114	0.0826 (0.9344)	D(LnRAIN(-1))	0.1006	1.4894 (0.1422)
D(LnFER)	0.1691	1.4373 (0.1564)	D(LnFER)	0.0815	1.3685 (0.1768)
D(LnFER(-1)	-0.0748	-0.6015 (0.5500)	D(LnFER(-1)	-0.0833	-1.2619 (0.2124)
D(LnIRRI)	-0.0068	-0.5910 (0.5570)	D(LnIRRI)	-0.0012	-0.2286 (0.8200)
D(LnIRRI(-1))	0.0036	0.3229 (0.7480)	D(LnIRRI(-1))	0.0072	1.3525 (0.1818)
D(LnCRI)	-0.0050	-0.0229 (0.9818)	D(LnCRI)	-0.1386	-1.2844 (0.2045)
D(LnCRI(-1))	0.0011	0.0386 (0.9693)	D(LnCRI(-1))	-0.0225	-1.6166 (0.1118)
ECM (-1)	-0.6665***	0.0003 (0.0003)	ECM(-1)	-0.3385**	-2.5524 (0.0136)
Dependent Variables: D(LnYSP)			***Dependent Variables: D(LnYWT)***		
C	-0.0005	-0.2541 (0.8003)	C	0.0021	0.0922 (0.9268)
D(LnYSP(-1))	-0.0882	-0.6299 (0.5314)	D(LnYWT(-1))	-0.0098	-0.0751 (0.9404)
D(LnASP)	0.0435	0.5169 (0.6073)	D(LnAWT)	-0.0093	-0.1148 (0.9090)
D(LnASP(-1))	0.1385	1.6063 (0.1140)	D(LnAAP(-1))	0.0936	1.1601 (0.2511)
D(LnRAIN)	-0.0144	-0.7827 (0.4372)	D(LnRAIN)	-0.0121	-0.6520 (0.5171)
D(LnRAIN(-1))	0.0805	0.5863 (0.5601)	D(LnRAIN(-1))	0.1368	0.9323 (0.3553)
D(LnFER)	0.0671	0.5331 (0.5961)	D(LnFER)	0.0255	0.2010 (0.8415)
D(LnFER(-1)	0.0490	0.3710 (0.7120)	D(LnFER(-1)	-0.0025	-0.0189 (0.9849)
D(LnIRRI)	-0.0002	-0.0192 (0.9847)	D(LnIRRI)	-0.0010	-0.0867 (0.9312)
D(LnIRRI(-1))	0.0047	0.4274 (0.6707)	D(LnIRRI(-1))	0.0034	0.2974 (0.7673)
D(LnCRI)	-0.1211	-0.5550 (0.5812)	D(LnCRI)	-0.2287	-0.9788 (0.3320)
D(LnCRI(-1))	0.0022	0.0782 (0.9379)	D(LnCRI(-1))	-0.0326	-1.0568 (0.2953)
ECM (-1)	-0.3453***	-2.9838 (0.0043)	ECM(-1)	-0.5452***	-4.0474 (0.0002)
Dependent Variables: D(LnYJT)			***Dependent Variables: D(LnYTR)***		
C	0.0101	0.5573 (0.5796)	C	0.0266*	1.8914 (0.0639)
D(LnYJT(-1))	-0.1113	-0.8071 (0.4231)	D(LnYTR(-1))	0.0968	1.0554 (0.2959)
D(LnAJT)	0.1756	1.0207 (0.3319)	D(LnATR)	-0.3302***	-4.1176 (0.0001)
D(LnAJT(-1))	-0.0216	-0.1392 (0.8898)	D(LnATR(-1))	0.0299	0.3809 (0.7047)
D(LnRAIN)	-0.0053	-0.3601 (0.7202)	D(LnRAIN)	0.0106	0.9338 (0.3546)
D(LnRAIN(-1))	0.1024	0.8411 (0.4039)	D(LnRAIN(-1))	0.0903	1.0156 (0.3143)
D(LnFER)	0.0473	0.4774 (0.6350)	D(LnFER)	-0.0666	-0.8599 (0.3936)
D(LnFER(-1)	-0.1005	-0.9634 (0.3396)	D(LnFER(-1)	-0.0265	-0.3261 (0.7456)
D(LnIRRI)	0.0126	1.3450 (0.1842)	D(LnIRRI)	0.0089	1.2343 (0.2224)
D(LnIRRI(-1))	-0.0024	-0.2686 (0.7892)	D(LnIRRI(-1))	0.0058	0.8098 (0.4216)
D(LnCRI)	-0.1501	-0.7863 (0.4351)	D(LnCRI)	-0.1214	-0.8590 (0.3941)
D(LnCRI(-1))	0.0291	1.1576 (0.2521)	D(LnCRI(-1))	-0.2221	-1.2099 (0.2316)
ECM (-1)	-0.7958***	-4.3302 (0.0001)	ECM(-1)	-0.8714***	-9.0149 (0.0000)

Table 6. (continuance).

Dependent Variables: D(LnYRM)			*Dependent Variables: D(LnYPO)*		
C	0.0011	0.0653 (0.9482)	C	-0.0299	-0.9080 (0.3679)
D(LnYRM(-1))	-0.1681	-1.2362 (0.2217)	D(LnYPO(-1))	-0.2151	-1.5377 (0.1299)
D(LnARM)	0.4692	1.6052 (0.1143)	D(LnAPO)	0.9481**	2.4110 (0.0193)
D(LnARM(-1))	0.1041	0.4206 (0.6757)	D(LnAPO(-1))	-0.3990	-0.9619 (0.3404)
D(LnRAIN)	-0.0010	-0.0750 (0.9404)	D(LnRAIN)	0.0309	1.1577 (0.2521)
D(LnRAIN(-1))	0.0048	0.0412 (0.9672)	D(LnRAIN(-1))	0.0205	0.1078 (0.9145)
D(LnFER)	0.0741	0.7215 (0.4737)	D(LnFER)	0.1389	0.8906 (0.3771)
D(LnFER(-1)	-0.0065	-0.0581 (0.9538)	D(LnFER(-1)	0.0869	0.5215 (0.6041)
D(LnIRRI)	-0.0081	-0.8115 (0.4206)	D(LnIRRI)	0.0178	1.2007 (0.2351)
D(LnIRRI(-1))	-0.0003	-0.0322 (0.9744)	D(LnIRRI(-1))	-0.0069	-0.4685 (0.6413)
D(LnCRI)	-0.7216	-0.3858 (0.7011)	D(LnCRI)	-0.0072	-0.0239 (0.9810)
D(LnCRI(-1))	-0.0050	-0.2028 (0.8400)	D(LnCRI(-1))	-0.0487	-1.3032 (0.1980)
ECM (-1)	-0.5139***	-3.2134 (0.0022)	ECM(-1)	-0.5030***	-3.3511 (0.0015)

Note: *, ** and **** indicates significant levels at 10%, 5% and 1% respectively
Figures in parentheses indicate probability value

3.6 Diagnostics Checking for Stability of the Model

The goodness of fit of the ARDL and error correction model, is tested by using the CUSUM and CUSUMQ tests after confirming the cointegration relationship among variables in order to examine stability of the model both in the short and long run. CUSUM and CUSUMQ tests are conducted based on the recursive regression residuals for both ARDL and ECM (Brown et al, 1975). If the plots of the statistics lie within the critical bounds at 5% level of significance, it can be concluded that calculated results of the coefficients of both ARDL model and ECM are stable. The stability of the model is shown in *Figure 1* and *2*, and goodness of fit of most of the model.

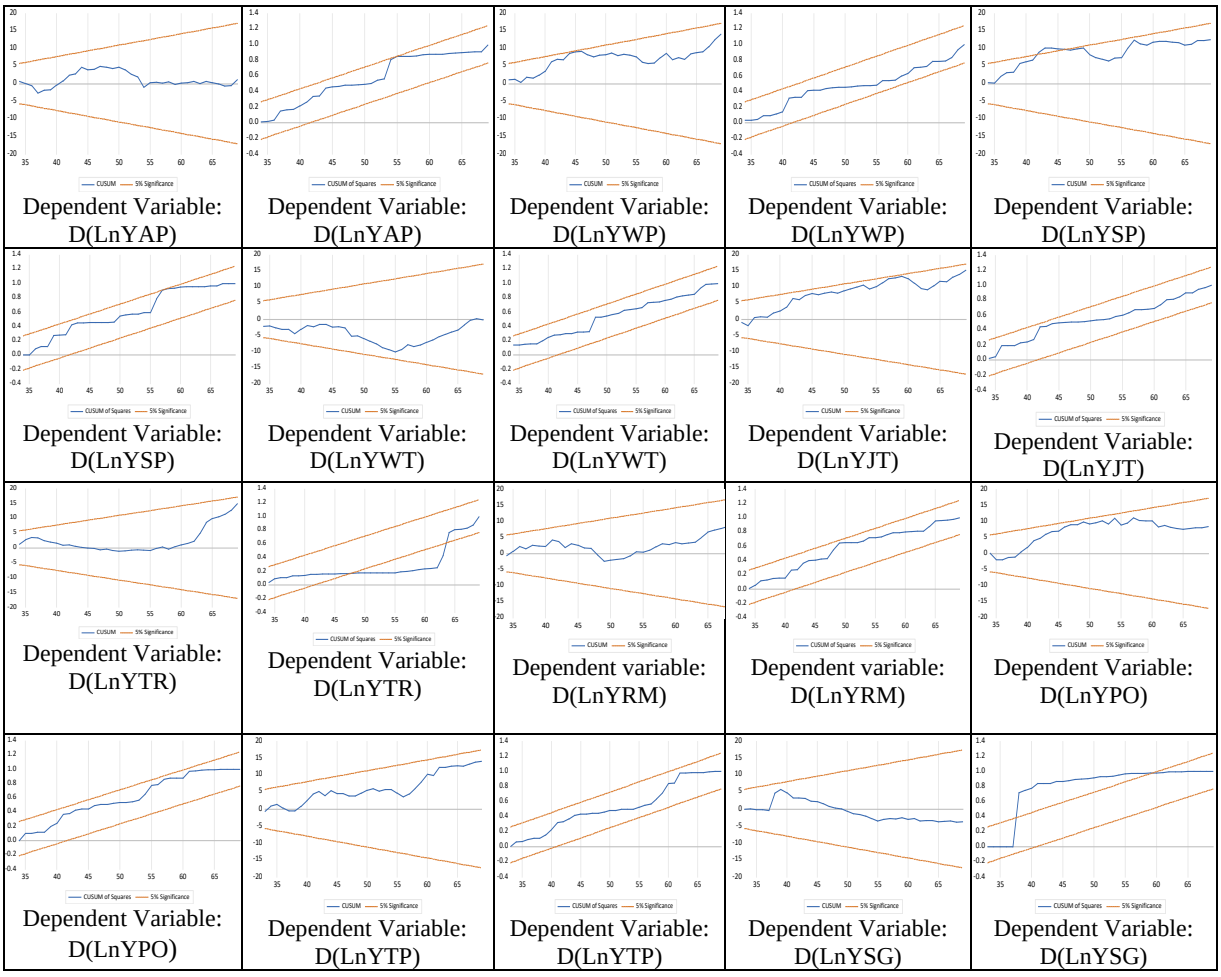

Figure 1. Plot of CUSUM (1st) and CUSUMQ (2nd) for Each Variable for Coefficient Stability of ARDL Model

is found to be significant, implying the model to be stable excepting for summer paddy for CUSUM (ARDL); and tur and sugarcane for CUSUMQ (ARDL) and tur CUSUM (ECM).

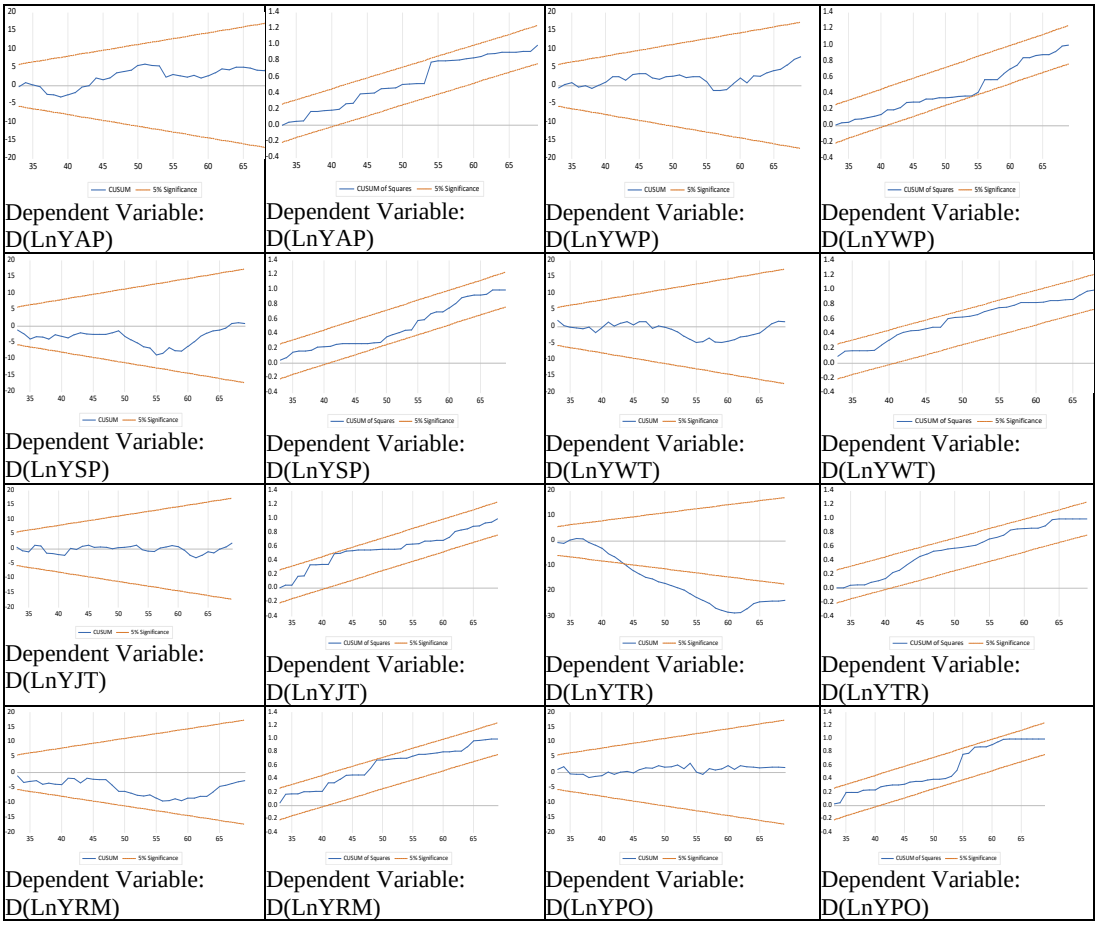

Figure 2. Plots of CUSUM (1st) and CUSUMQ (2nd) for Each Variable for Coefficient Stability for Error Correction Model

3.7 Changes in Cropping Pattern Examined through Diversification Index and Proportion of GCA under Various Crops

Values of Herfindahl and Simpson Indices reveal gradual diversification of crops in Assam over the years but with a slower pace (*Table 7*). Cropping pattern in any region ultimately depends upon food habit, prices, agro-climatic conditions, market avenues, government policies and infrastructure. Cropping pattern in Assam is still dominated by paddy (rice) with a total 60.43 per cent of GCA under cultivation during 2017-20 (*Table 8*). Area under autumn paddy increased marginally in 1950s and after 1970 it started declining till 2017-20. Development of minor irrigation (shallow tube-well) has given some momentum to cultivators of summer paddy. The harvest time for summer paddy is March to May. So, the farmers find it convenient to cultivate this in order to avoid the risk of flood that affects more frequently in case of autumn paddy.

The autumn and winter paddy are found to lose area to some relatively more remunerative crops in the earlier years. But the process has lost momentum in past two decades. Cultivation of wheat increased during early 1980s but declined afterwards till 2017-20. It is now more concentrated in summer paddy, potato, and mustard. In some region however, the cultivation of inferior crops has increased due to poor irrigation facility, agro-infrastructure and technological support as well as risk averse behavior of cultivators (De and Bodosa, 2015).

Table 7. Herfindahl and Simpson Indices of Selected Crops in Assam

Year	*Herfindahl Index*	*Simpson Index*
1951-54	0.93	0.07
1961-64	0.90	0.09
1971-74	0.85	0.15
1981-84	0.74	0.26
1991-94	0.74	0.26
2001-04	0.73	0.27
2011-14	0.60	0.40
2017-20	0.60	0.40

Source: Computed from data published by the Directorate of Economics and Statistics, Government of Assam, Statistical Handbook of Assam (Various Issues).

Table 8. Changes in Share of Area under Crops to GCA (Per cent)

Crops	*1951-54*	*1961-64*	*1971-74*	*1981-84*	*1991-94*	*2001-04*	*2011-14*	*2017-20*
Autumn Paddy	16.07	18.67	19.53	18.09	17.33	12.68	5.98	3.55
Winter Paddy	58.32	55.32	52.19	48.60	47.88	47.31	45.45	46.92
Summer Paddy	0.29	0.45	1.31	1.11	3.67	8.80	9.60	9.96
Total Paddy	74.69	74.44	73.03	67.80	68.89	68.79	61.03	60.43
Wheat	0.11	0.13	1.74	3.00	2.08	1.91	0.85	0.38
Tur	0.18	0.12	0.22	0.25	0.17	0.19	0.14	0.14
Rape & Mustard	5.38	5.16	5.28	7.62	7.92	7.21	6.53	7.12
Jute	5.52	5.52	4.89	3.29	2.45	1.81	1.62	1.66
Potato	0.89	0.99	0.96	1.25	1.72	2.11	2.36	2.59
Sugarcane	1.19	1.17	1.27	1.46	1.03	0.70	0.70	0.76

Source: Computed from data published by the Directorate of Economics and Statistics, Government of Assam, Statistical Handbook of Assam (Various Issues).

3.8 Decomposition Analysis

Growth in agricultural production is the result of growth in area, yield, cropping pattern and interactions among themselves. Thus, decomposition analysis is carried out to compute the effect of area, yield, cropping pattern and their interactions to the changes in output. During the period prior to Green Revolution, 28.08 per cent of the growth in agricultural output was contributed by area growth, 18.72 per cent by yield growth and 36.40 per cent due to cropping pattern effect (*Table 9*). The combined interaction effects resulted in 16.8 per cent of change in total agricultural output of which, interaction of area and cropping pattern was the highest. Thus, during the first phase after Independence, cropping pattern change was the largest contributor, followed by area and then yield to the growth of agricultural output. During Period II (Green Revolution) yield effect was the highest (43.95 per cent) for the application of seed-fertilizer-irrigation technology, while the area effect was reduced to 15.67 per cent, and area-yield interaction effect was 18.19 per cent and cropping pattern effect also declined to 11.97 per cent. The other interaction effects were negligible.

During period III, yield effect continued to increase and remains the highest contributor to the growing agricultural output (80.21 per cent); followed by area effect (28.75 per cent) and the interaction of area & yield (13.36 per cent). The other factors such as cropping pattern and the interaction of area & cropping pattern, cropping pattern & yield, and area, yield and cropping pattern have negative contribution to the agricultural output growth. The results suggest that the source of growth have changed dramatically over different periods. Since the scope of area expansion became insignificant, its contribution to the increased output has been diminishing gradually. The yield effect increased significantly over the periods due to growing use of modern agricultural inputs and implements through government support and the efforts of stakeholders. However, Assam still lags behind the agriculturally developed states of the country in terms of yield in crops as well as use of modern inputs. Thus, there are significant scopes in these fronts and efforts need to be directed to improve yield and diversify cultivation practices towards higher-value crops to further raise agricultural earning.

Table 9: Relative Contribution of Various Components to the Growth of Selected Crops Total Output in Assam during 1951-52 to 2019-20 (per cent)

Components	*Period I*	*Period II*	*Period III*
Area Effect	28.08	15.67	28.75
Yield Effect	18.72	43.95	80.21
Cropping Pattern Effect	36.40	11.97	-11.40
Area & Cropping Pattern Effect	7.31	4.95	-1.90
Area & Yield Effect	3.76	18.19	13.36
Cropping Pattern & Yield Effect	4.77	3.73	-7.73
Area, Yield & Cropping Pattern Effect	0.96	1.54	-1.29

Source: Computed from data published by the Directorate of Economics and Statistics, Government of Assam, Statistical Handbook of Assam (Various Issues).

4. Conclusions

This paper analyzes the pattern of agricultural growth in Assam, India since independence. Though winter paddy, is the principal crop for being the staple food item, its share in gross cultivated area declined over time. Mustard, potato and summer paddy however recorded continuous growth, which got accelerated and occupied central position in crop diversity during economic reform period along with commercialization of agriculture, and supported by much needed modern technological inputs and implements. Notwithstanding the slow pace, the diversity and adaptability followed a similar pattern like that of the major eastern states of India (De, 2003) along with the progress of garden crops especially tea (De and Bodosa, 2015; De and Pal, 2019).

The growth of production of paddy, wheat, tur and sugarcane during Period I was mainly due to area expansion and in Period II due to both yield and area growth. However, this increase in production and area was short-lived for autumn paddy, wheat and sugarcane, but for others it has been significantly positive. Yield growth rate has been on continuous rise for all the crops except potato and sugarcane. Deceleration in area and production continued for jute, autumn paddy, tur, wheat during Period III but rate of decline in production was slower than that of area growth with accelerated growth in yield. Autumn and winter paddy, jute and sugarcane have been losing area to summer paddy, mustard and potato that recorded steady growths in area and yield (De and Bodosa, 2015). HYV paddy cultivation accounts to 78 per cent of total paddy during 2017-20, which was 40 per cent during 1981-84. Also, diversification towards some low value crops has been observed in the previous decades due to uncertain weather conditions and unmatched progress of irrigation. It may be highlighted that area under jute has been reduced in Assam along with its production. As jute requires hot and humid conditions to grow, it depends on wellmaintained irrigation for the erratic behaviour of rainfall. But the irrigation facility is not well developed in Assam. This possibly explains the reduction in area under cultivation of jute in Assam.

The decomposition analysis showed that area, yield and the area-yield interaction effects have positive effects on agricultural output. Initially, effect of cropping pattern and area assumed greater role in the growth of agricultural output, but their effects declined and yield effect became the strongest during period II and III, with the gradual expansion of modern technology. In Assam use of modern technology got slow progress and lagged behind other parts of Indiaby around two decades. There is a visible gap in utilization of irrigation potential. Out of 1002 thousand hectares irrigation potential created in 2017-20, net area irrigated was only 209 thousand hectares (about 21 per cent) with low coverage of canal irrigation.

The ARDL bounds testing approach confirmed the long-term relationship of yield of all varieties of paddy, wheat, tur, mustard, potato and jute with the so-called advanced technology. Area and consumption of fertilizer are positively associated with the yield of winter and summer paddy, but rainfall and cropping intensity are inversely related to the yield of winter paddy. For wheat, cropping intensity is inversely related to the yield, while irrigation caused improved yield of jute though ultimately it saw a negative trend in area allocation over the years for the limited irrigation capacity utilisation. For rape & mustard it was mostly cropping intensity that has positively affected yield in the long run.

The long run cointegrating relation and ECM reveals self-adjustment process of any disequilibrium occurring in all the equations. The CUSUM and CUSUMQ tests confirm the goodness of fit of the models. Estimates of ARDL, ECM and graphs of CUSUM and CUSUMQ shows the long-run and short-run impact of elasticities of

area under cultivation, rainfall, fertilizer, cropping intensity and irrigation on yield of crops grown in Assam. This results is validated with the help of CUSUM and CUSUMQ graphs, which confirms the stability of ARDL and ECM model for majority of the crops taken under consideration.

Use of agricultural implements has been rising but not at a slower pace to enhance agricultural productivity and efficiency of farmers remarkably. Such slow progress of modern farming technique hinders adoption of desired crop diversity and contribution of cropping pattern change has not been rising in desired direction. Adoption of seed-fertilizer-irrigation technology in Assam is still at the midway as compared to the developed agricultural zones of India. Thus, there is still enough space to improve the productivity of crops further and judicious use of resources to raise profitability of the farmers through crop diversity. The recommendations to improve yield on crops can be designed according to crop specific characteristics. As each crop requires different environment and inputs for its growth, the focus should be placed specifically on physical and technological inputs, especially in extreme climatic conditions. Technological innovation in any agro-climatic zone may help in moderating adverse impacts of extreme climatic events and choose the desired cropping pattern.

Although the study is conducted in Assam, the largest North-Eastern state of India, under the similar agro-climatic conditions of sub-Himalayan India, the same result can be replicated for other areas too. Technological breakthrough is very important to benefit the farmers in the long run. Irrigation facility should be created to respond to erratic rainfall. Use of chemical fertilizer has been significant in improving yield of crops. However, considering sustainability approach as observed in other regions, overdose of chemical fertilizer (wherever observed) needs to be sensitized (Khajuria, 2016; Bora, 2022). The farmers should be given proper training on soil testing and appropriate recommendation of fertilizer dosage. Infrastructural facility such as cold storage needs to be developed for the preservation of perishable crops. Thus, the outcome of this study is relevant and has significant policy implications for any region with varied agroclimatic condition and depending on the local topographic and climatic conditions; suitable cropping pattern with technology needs to be applied.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Farklı Dikim Sıklıkları ve Hasat Zamanının *Dracocephalum moldavica* L. (Moldovya Ejderi)'nın Verim ve Kalitesine Etkileri

The Effects of Different Planting Densitiy and Harvesting Time on the Yield and Quality of *Dracocephalum moldavica* L. (Moldavian dragonhead)

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Öz

Dracocephalum moldavica L. (Moldovya ejderi) bitkisi birçok ülkede geleneksel tıpta mide rahatlatıcı, sindirim kolaylaştırıcı, yatıştırıcı olarak kullanımının yanı sıra kalp hastalıkları, damar tıkanıklıkları, tansiyon, migren, baş ve diş ağrısı tedavisinde kullanılmaktadır. Ülkemiz florasında *Dracocephalum* cinsine ait birçok tür bulunurken, *D. moldavica* türü doğal olarak yetişmemektedir. Bitkinin Türkiye'de yetiştiriciliği üzerine çalışma bulunmamaktadır. Bitki dikim sıklığı ve hasat zamanı bitki verim ve kalitesi üzerine önemli etkileri olan yetiştirme etmenlerindendir. Bu sebeplerle *Dracocephalum moldavica* (Moldovya ejderi) bitkisinde verim ve kalite özellikleri üzerine dikim sıklıklarının (40×25 cm ve 60×25 cm) ve hasat zamanlarının (çiçeklenme öncesi ve tam çiçeklenme) etkilerini araştırmak hedeflenmiştir. 2017 yılında yürütülen araştırma sonuçlarına göre dikim sıklığının etkisi dal sayısı, taze ve drog herba, drog yaprak verimi üzerinde, hasat zamanının etkisi; bitki boyu, taze herba, drog herba, drog yaprak verimi, uçucu yağ oranı üzerinde istatistiki olarak önemli; interaksiyonun etkisi ise incelenen özellikler üzerinde önemli bulunmamıştır. Araştırma sonucunda; bitki boyu değerleri: 57.91-63.08 cm, dal sayısı 8-12 adet/bitki, taze herba verimi 537.26-791.54 kg da^{-1}, drog yaprak verimi 65.36-122.23 kg da^{-1}, drog herba verimi 124.05-194.41 kg da^{-1}, uçucu yağ oranı % 0.276-0.375 olarak tespit edilmiştir. Hasat zamanı bakımından incelen bütün özellikler tam çiçeklenme döneminde artış göstermiştir. Bitki boyu, taze herba, drog yaprak ve herba verimi en yüksek değerleri 40x25 dikim sıklığında elde edilmiştir. Uçucu yağ ana bileşenlerini geranil asetat (%53.635-54.723), gerenial (%16.229-17.396), neral (%11.729-12.661), geraniol (%5.780-6.623) toplamda %88.203-88.955 oranlarında oluşturmaktadır. Geranil asetat oranın yüksekliği bitkinin Çukurova koşullarında doğal bir geranil asetat kaynağı olarak kullanılabileceğini düşündürmektedir. Elde ettiğimiz veriler doğrultusunda Moldovya ejderi için en uygun hasat zamanı tam çiçeklenme dönemi, en uygun bitki dikim sıklığı ise 40×25 cm olarak tavsiye edilmektedir.

Anahtar Kelimeler: *Dracocephalum moldavica* L., Moldovya ejderi, Dikim sıklığı, Hasat zamanı, Uçucu yağ

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Abstract

Dracocephalum moldavica L. (Moldovian dragon) is used in traditional medicine in many countries as a stomach relaxant, digestive facilitator, sedative, as well as in the treatment of heart diseases, vascular occlusion, blood pressure, migraine, headache and toothache. While many species belong to the genus *Dracocephalum* in the flora of our country, the species *D. moldavica* does not grow naturally. There are no studies on the cultivation of the plant in Turkey. Planting frequency and harvesting time are cultivation factors that have important effects on plant yield and quality. For these reasons, it was aimed to investigate the effects of planting densities (40×25 cm and 60×25 cm) and harvest times (pre-flowering and full flowering) on yield and quality characteristics of *Dracocephalum moldavica* (Moldovan dragon). According to the results of the research conducted in 2017, the effect of planting frequency on the number of branches, fresh and culinary herb, culinary leaf yield, the effect of harvest time on plant height, fresh herb, culinary herb, culinary herb, culinary leaf yield, and essential oil ratio was found to be statistically significant; the effect of the interaction was not found to be significant on the studied traits. As a result of the research; plant height values: 57.91-63.08 cm, number of branches 8-12 pieces/plant, fresh herb yield 537.26-791.54 kg da-1, dry leaf yield 65.36-122.23 kg da-1, dry herb yield 124.05-194.41 kg da-1, essential oil content 0.276-0.375%. All traits analyzed in terms of harvest time increased during the full flowering period. The highest values of plant height, fresh herb, culm leaf and herb yield were obtained at 40x25 planting density. The main components of essential oil were geranyl acetate (53.635-54.723%), gerenial (16.229-17.396%), neral (11.729-12.661%), geraniol (5.780-6.623%) with a total of 88.203-88.955%. The high rate of geranyl acetate suggests that the plant can be used as a natural source of geranyl acetate in Çukurova conditions. In line with the data we obtained, the most suitable harvest time for Moldovan dragon is recommended as full flowering period and the most suitable planting density is recommended as 40×25 cm.

Keywords: *Dracocephalum moldavica* L., Moldavian dragonhead, Planting density, Harvest time, Essential oil

1.Giriş

Moldovya ejderi (*Dracocephalum moldavica* L.) Orta Asya kökenli olup, deniz seviyesinden 2700-3100 m yüksekliğe kadar Mısır, Çin, Moğolistan ve Himalayalar da yetiştirilen Lamiaceae familyasına ait yaklaşık 40 türü bulunan tek yıllık aromatik bir bitkidir (Holm ve ark., 1988). Bitkinin çiçek, gövde ve yaprak yüzeyinde bulunan trikomların yaydığı narenciye ve limon otuna (*Melissa officinalis* L.) benzer koku, arılar tarafından cezbedici bulunmaktadır. Bitkinin bal kapasitesinin 129-650 kg/hektar olduğu tahmin edilmektedir (Dmitruk ve ark., 2018). Batı Azerbaycan (İran) geleneksel tıbbında mide rahatlatıcı, sindirim kolaylaştırıcı, yatıştırıcı olarak kullanılan bitki Uygur geleneksel tıbbında kalp hastalıkları, damar tıkanıklıkları, tansiyon, migren, baş ve diş ağrısı tedavisinde kullanılmıştır (Miraldi ve ark. 2001; Sultan ve ark., 2008). Günümüzde parfüm ve sabun üretiminde, reçellerin, alkollü içeceklerin, şurupların ve konserve balıkların tatlandırılmasında kullanılmaktadır. Bitkisel çay olarak tüketildiğinde ise mide rahatlatıcı, gerginlik azaltıcı ve hamile kadınlar için kusma refleksini azaltıcı etkiler göstermektedir (Ştefania ve ark. 2018).

Moldovya ejderi uçucu yağ oranı çeşitli araştırma sonuçlarına göre %0.10-0.70 arasında değişmektedir (Shatar ve Altantsetseg, 2000). Uçucu yağ içeriğini büyük oranda geranial, geranil asetat, neral, linalol ve nerol gibi oksijenli monoterpenler oluşturmaktadır (Muntean ve ark. 2016). Uçucu yağ doğal insektisit özellik, antimikrobiyal aktivite ve analjezik etki göstermektedir (Chu ve ark., 2011; Maham ve ark., 2013; Ehsani ve ark., 2017). Bitki ekstraktlarının biyolojik aktivitesinin yüksek olduğu antioksidan aktivite ve antitümör özellik gösterdiği belirlenmiştir (Chachoyan ve Oganesyan, 1996; Povilaityté ve ark., 2001; Dastmalchi ve ark., 2007). Hayvanlar üzerinde yapılan çalışmalarda sedatif ve kardiyak etkisi kanıtlanmıştır (Najafi ve ark., 2009; Martínez-Vázquez ve ark., 2012).

Tarımda temel hedeflerden biri, istenen verimi elde etmek için çevresel kaynakların bitki tarafından en iyi şekilde kullanılabilirliğini sağlamaktır. Bitkilerin çevresel kaynaklardan (toprak suyu ve besin içeriği, güneş ışığı gibi) faydalanma miktarını etkileyen faktörlerden biri de bitki yoğunluğudur (Perrott et al., 2018). Bitkiler iyi bir vejetatif gelişim ve biyokütle artışı için optimum bitki yoğunluğu isterler (Morla ve ark., 2018) Optimum bitki yoğunluğu, bitki tarafından en yüksek ışık absorpsiyonunun yapılabildiği, en yüksek yaprak alanı indeksine ve bunların sonucunda en iyi bitki veriminin elde edildiği bitki yoğunluğudur (Basiri ve Nadjafi, 2019). Diğer bir deyişle ekim sıklığı optimum düzeyden fazla ise çevre faktörleri bitki için yeterli olmayacak, optimum seviyenin altında ise bitki çevre faktörlerinden etkin bir şekilde yararlanamayacaktır. Abdossi ve ark. (2015) İran koşullarında *Dracocephalum moldavica*' da en yüksek taze ve drog herba ile uçucu yağ verimini 30x10 cm dikim sıklığında; en yüksek uçucu yağ oranını ise 30x30 cm dikim sıklığında elde etmişlerdir. Hussein ve ark. (2006) Mısır'da yürüttükleri çalışmada 60x30 sıklığında 3.6 t ha^{-1} kompost gübre uygulamasına tabi tuttukları bitkilerin en yüksek uçucu yağ oranı ve bileşenlerine sahip olduğunu bildirmişlerdir. *Dracocephalum moldavica* L.'nın verim ve kalite bileşenleri için en uygun ekim sıklığı üzerine sınırlı sayıda araştırma yapılmıştır.

Tıbbi ve aromatik bitkiler içerdikleri sekonder metabolitler nedeniyle kültürü yapılan bitkilerdir. Sekonder metabolitlerin bitki bünyesinde değişimine etki eden faktörlerden biri de bitkinin gelişim evreleridir (Baydar, 2016). Bu nedenle yetiştiriciliği yapılacak bitkinin kullanım amacına göre en yüksek uçucu yağ verimi ve kompozisyonu elde etmek için doğru hasat zamanı çok önemlidir. Mohtashami ve ark., (2013) *Dracocephalum moldavica*' da sekonder metabolit içeriğinin gelişim evreleriyle yakından ilişkisi olduğunu en yüksek karotenoid, flavon ve flavonol seviyelerine tam çiçeklenme döneminde, en yüksek antioksidan aktivite ve uçucu yağ yüzdesi de meyve tutumu aşamasında kaydedildiğini bildirmişlerdir. Khalili ve Amirnia, (2014) bitkinin en yüksek uçucu yağ oranının tam çiçeklenme evresinde elde dildiğini belirlemişlerdir.

"Ejderotu" olarak bilinen *Drococephalum* cinsine ait ülkemiz florasında bulunan birçok tür (*D. austriacum, D. ruyschiana, D. multicaule* var. *multicaule, D. multicaule* var. *setigerum ve D. aucheri*) arasında *D. moldavica* bulunmamaktadır (Anonim, 2022). Ayrıca *Dracocephalum moldavica* L. bitkisinin Türkiye 'de yetiştiriciliği üzerine çalışma yapılmamıştır. Bu nedenle Çukurova koşullarında farklı dikim sıklıkları ve hasat zamanlarının bitkisel özellikleri ve verim değerlerinin yanı sıra uçucu yağ oranı ve bileşenleri üzerindeki etkileri araştırılmıştır.

2.Materyal ve Metot

2.1 Bitki Materyali

Araştırmanın bitki materyalini oluşturan Moldovya ejderi (*Dracocephalum moldavica* L.) tohumları yurt dışından (Nojous Seklos firması-Litvanya) getirtilmiştir. *Lamiaceae* familyasına ait olan bitki çok sayıda gövdeye (6'ya kadar) sahip olup, genellikle dik gelişir ve 80 cm'e kadar boylanır. Yapraklar dikdörtgen ila oval-üçgen şeklinde 1.7-2.4 cm uzunluğunda 0.8-1.2 cm genişliğinde, kenarları tırtıklıdır. Mavi-mor taç yapraklı çiçekler, yaprak koltuklarında yalancı sarmallar şeklinde büyürler (Jeong ve ark., 2016).

2.2 Deneme Yeri

Araştırma 2017 yılında Çukurova Üniversitesi Ziraat Fakültesi Tarla Bitkileri Araştırma ve Uygulama Alanında kurulmuştur. Akdeniz bölgesinin doğusunda kalan Adana ilinde yazları sıcak ve kurak, kışları ılık ve yağışlı geçmektedir. Araştırma alanına ait maksimum, minimum, ortalama sıcaklık ve toplam yağış değerleri *Tablo 1*'de verilmiştir. Bitkilerin arazide geçirdiği Mart, Nisan, Mayıs ve Haziran aylarında ortalama sıcaklık ve toplam yağış miktarları uzun yıllar ortalaması değerleriyle benzerdir. Deneme yerinin 0-30 cm derinlikten alınan toprak örneklerinin Çukurova Üniversitesi Ziraat Fakültesi Toprak Bilimi ve Bitki Besleme Bölümü Laboratuvarında yapılan analizin sonuçları *Tablo 2*'de verilmiştir. Denemenin yürütüldüğü alan, Seyhan nehri yan derelerinin getirdiği çok genç alüviyal topraklardan oluşmuştur. A ve C horizonlarına sahip olup, orta derin ve derindir. Organik madde oranı alt katmanlarda azalmış tınlı topraklardır.

Tablo 1: Deneme yerine ait bazı iklim verileri

Table 1. Some climatic data of the experimental area

Aylar/Months	Sıcaklık (°C) / Temperatuare(°C)						Yağış(mm)/Rain(mm)	
	Maximum		Minimum		Ortalama/ Average			
	2017	Uzun Yıllar Long-term	2017	Uzun Yıllar Long-term	2017	Uzun Yıllar Long-term	2017	Uzun Yıllar Long-term
Ocak/January	19.1	26.5	-0.6	-8.1	8.7	9.5	49.6	107.6
Şubat/February	26.2	28.5	-1.3	-6.6	10.7	10.5	0.6	90.0
Mart/March	25.6	32.0	6.4	-4.9	15.2	13.4	65.2	65.4
Nisan/April	33.1	37.5	8.5	-1.3	18.5	17.5	63.2	51.3
Mayıs/May	33.7	41.3	13.2	5.6	21.8	21.7	44.4	47.3
Haziran/June	37.5	42.8	16.4	13.7	26.2	25.6	19.4	20.4

Turkish State Meteorological Service

Tablo 2. Deneme yerinin toprak özellikleri

Table 2. Soil characteristics of the experimental area

Yapı /Texture			pH	E.C.	$CaCO_3$	P_2O_5	K_2O	Zn	Fe	Mn	Cu
Kum Sand (%)	Silt (%)	Kil Clay (%)	(%)	(Mmhos/cm)	(%)	(kg da-1)	(kg da-1)	(ppm)	(ppm)	(ppm)	(ppm)
24.3	33.1	42.6	7.73	0.15	34.1	16.4	99.1	1.7	11.3	2.9	1.6

2.3. Uygulama ve Deneme Deseni

Moldovya ejderi (*Dracocephalum moldavica* L.) tohumları sera içinde 15.01.2017 tarihinde viyollere ekilmiş, 03.02.2017 tarihinde çıkışlar tamamlanmıştır. Fideler yaklaşık 10 cm boylandığında 29.03.2017 tarihinde araştırma alanına şaşırtılmıştır. Dikim sıklığı olarak 40 ve 60 cm sıra aralığı seçilmiş olup, sıra üzeri 25 cm olmak üzere sabit tutulmuştur. Parseller dört sıra, her sırada 10 bitki olacak şekilde toplam 40 bitkiden oluşmaktadır. Dikim sıklığı 40x25 cm olan parseller 1.6 x 2.5 metre; 60x25 cm olan parseller ise 2.4 x 2.5 metre boyutlarındadır. Hasat zamanları olarak da çiçeklenme öncesi ve tam çiçeklenme dönemleri seçilmiştir. Araştırma tesadüf bloklarında bölünmüş parseller deneme desenine göre 3 tekerrürlü olarak kurulmuş olup, dikim sıklıkları ana parselleri, hasat zamanları alt parselleri oluşturmuştur. Araştırmada düzenli olarak yağmurlama sulama yapılmıştır.

2.4. Hasat ve Verilerin Elde edilmesi

Bitkiler çiçeklenme öncesi (26.05.2017) ve tam çiçeklenme (09.06.2017) olmak üzere iki farklı hasat zamanında toprak yüzeyinde yaklaşık 5 cm mesafeden biçilerek hasat edilmiştir. Bitkiler hasat edilmeden önce parselin orta sıralarından seçilen rastgele 10 bitkinin bitki boyu ve dal sayısı tespit edilmiştir. Her parselden kenar iki sıra ayrılarak orta sıradaki bitkiler hasat edilmiştir. Hasat edilen bitkiler yaş olarak tartılarak yeşil herba verimi hesaplanmıştır. Drog herba ve yaprak verimleri için bitkiler gölgede oda sıcaklığında nem oranı %10'a düşene kadar kurutularak tartılmıştır.

2.5. Uçucu Yağ İzolasyonu

Kuru yapraklardan 30 gram örnek alınarak 1000 ml'lik balonlara konulmuş ve üzerine 300 ml su konularak 3 saat süre ile Neo Clevenger cihazında distilasyona tabi tutulmuştur. Uçucu yağ miktarı volümetrik olarak ölçülerek kullanılan örnek miktarına göre % olarak hesaplanmıştır. Elde edilen uçucu yağlar cam viallere alınarak analiz yapılana kadar -18 ºC' de derin dondurucuda muhafaza edilmiştir.

2.6. Uçucu Yağ Bileşenlerinin Belirlenmesi

Uçucu yağ bileşenleri Çukurova Üniversitesi Merkezi Araştırma Laboratuvarı'nda Thermo-Scientific GC/MS cihazı ile (0.25 mm iç çapx60, film kalınlığı 0,25 µm) ZB-5 kapiler kolon kullanılarak yapılmıştır. Sıcaklık programı: 50°C' den 240°C' ye dakikada 3°C' lık artışla ulaşır ve enjeksiyon sıcaklığı 200°C' ye ayarlanmıştır. Taşıyıcı gaz olarak akış hızı 1 ml/dak. olan helyum (He) kullanılarak her bileşen, kütle Spektrumlarının Wiley kütüphanesinden karşılaştırması ile tanımlanmıştır.

2.7. Elde Edilen Verilerin Analizi

Araştırmadan elde edilen tüm veriler Tesadüf Bloklarında Bölünmüş Parseller Deneme Desenine göre JMP programında varyans analizine tabi tutulmuştur. İncelenen özelliklere ait varyans analizinde önemlilik testleri %1 ve %5 düzeyinde yapılmıştır. Özelliklerin ortalamalarının gruplandırılması ise %5 olasılık düzeyinde EGF (LSD) testi ile yapılmıştır.

3.Araştırma Sonuçları ve Tartışma

Araştırmada incelenen özelliklere ait varyans analiz sonuçları *Tablo 3*'te verilmiştir.

Tablo 3. Dracocephalum moldavica* L.*' da incelenen özelliklerin varyans analizi

Tablo 3. Analysis of variance on traits examined in Dracocephalum moldavica L.

		Kareler Ortalaması / Mean of Square					
Varyasyon Kaynağı Source of Variation	**S.D Df**	**Bitki Boyu Plant Height (cm)**	**Dal Sayısı Number of branches (per/plant)**	**Taze Herba Verimi Fresh Weight (kg da^{-1})**	**Drog Yaprak Verimi Dry Leaf Weight (kg da$^{-1)}$**	**Drog Herba Verimi Dry weight (kg da^{-1})**	**Uçucu Yağ Oranı Essential Oil Ratio (%)**
Blok/ Replication	2	6,81	0,27	691,421	75,8575	378,876	3,33e-05
Hasat Zamanı/ Harvesting Time	1	80,08*	13,02$^{ö.d}$	52843,8*	9701,45*	14022*	0.02901**
Hata / Error (A)	2	2.85	0.27	707.862	121.901	198.851	3.33e-05
Dikim Sıklığı/ Plant Density (B)	1	5.33$^{ö.d}$	46.02**	193975**	2059.32*	8174.52*	0.00067$^{ö.d}$
A x B	1	2.08$^{ö.d}$	1.02$^{ö.d}$	7624.51$^{ö.d}$	1.50e-28$^{ö.d}$	406.003$^{ö.d}$	8.33e-06$^{ö.d}$
Hata / Error (B)	4	0.70	1.77	1887.3	214.6	410.99	0.000217
V.K / C.V (%)		1.38	13.3	6.54	15.06	12.82	4.3

S.D: serbestlik derecesi, *,**,ö.d: sırasıyla istatistiki olarak 0.05 ve 0.01 düzeyinde önemli, önemli değil

3.1. Bitki Boyu

Yapılan varyans analizi sonucuna göre, Moldovya ejderi (*Dracocephalum moldavica* L.) bitkisinde bitki boyu üzerine hasat zamanlarının; önemli (P<0.05) bir etkiye sahip olduğu, dikim sıklığının ve interaksiyonunun ise önemli bir etkiye sahip olmadığı belirlenmiştir (*Tablo 3*). Bitki dikim sıklığı ortalama değerleri incelendiğinde aradaki farklılık önemli olmamakla birlikte en yüksek bitki boyu 61.16 cm 40x25 cm dikim sıklığında, en düşük

bitki boyu 59.87 cm 60x25cm dikim sıklığında elde edilmiştir. En yüksek bitki boyu 63.08 cm tam çiçeklenme döneminde, en düşük bitki boyu 57.9cm çiçeklenme öncesi hasat edilen bitkilerde elde edilmiştir (*Tablo 4*).

Dikim sıklığı x hasat zamanı interaksiyon değerleri incelendiğinde aralarındaki farklılık önemli olmamakla birlikte, en yüksek bitki boyu değerleri tam çiçeklenme döneminde, 64.16 cm ile 40x25 cm, 62.00 cm ile 60x25cm dikim sıklığında elde edilmiştir. Ahmadi ve Hadipanah (2014) en yüksek bitki boyunu 56.26 cm ile 30x30 cm dikim sıklığında bulmuşlardır. Hussein ve ark. (2006) iki yıl süreyle farklı dikim sıklıklarının ve gübre dozlarının bitki üzerine etkisini incelemişlerdir. Araştırmada en yüksek bitki boyunu 60x20 cm dikim sıklığında 64.0-70.57 cm, en düşük bitki boyu 60x40 cm dikim sıklığında 57.67-67.10 cm olarak belirlenmiştir. Çalışmamız, yapılan araştırma sonuçlarına benzer veya ortasında bir değer almıştır. Bitki boyu değerleri belli bir sınırın üzerinde seyredip; ekim zamanı, bitki sıklığı ve farklı gübre uygulamalarından kaynaklı değişiklik göstermektedir.

Moldovya ejderi'nde çiçeklenme öncesinden tam çiçeklenme dönemine doğru bitki boyunda artış tespit edilmesi bitkinin büyümeye, yeşil aksamını geliştirmeye devam ettiğini göstermektedir. Daha önce farklı bitkiler (kekik, çördük, oğul otu) üzerinde yapılan çalışmalarda da bitki boyu üzerinde hasat zamanının etkili olduğu görülmüştür (Badi ve ark. 2004; Güler, 2007; Kızıl, 2009). Araştırmamızda bitki sıklığının artmasına bağlı olarak bitki boyları da artmıştır (*Tablo 4*). Bitki sıklığının artması bitkilerin yaşam kaynağı olan Güneş ışığı için rekabet etmesine sebep olarak daha uzun boylu olmalarını sağlamıştır. Benzer şekilde Hussein ve ark. (2006), Moldovya ejderi üzerine yaptıkları çalışmada bitki dikim sıklığı arttıkça bitki boyunda önemli bir artış olduğunu belirtmişlerdir.

3.2. Dal Sayısı

Varyans analizi sonucuna göre, Moldovya ejderi (*Dracocephalum moldavica* L.) bitkisinde dal sayısı üzerine dikim sıklığının önemli ($P<0.01$) bir etkiye sahip olduğu, hasat zamanı ve interaksiyonunun ise önemli bir etkiye sahip olmadığı belirlenmiştir (*Tablo 3).* Hasat zamanı ortalama değerleri incelendiğinde ise en yüksek dal sayısını tam çiçeklenme döneminde (11 adet/bitki), en düşük dal sayısı ise çiçeklenme öncesinde (9 adet/bitki) belirlenmiştir (*Tablo 4*). Dikim sıklığı ortalama değerleri incelendiğinde en yüksek dal sayısı 60x25 dikim sıklığında 12.00 adet/bitki, en düşük dal sayısı da 40x25 dikim sıklığında 8.00 adet/bitki olarak belirlenmiştir (*Tablo 4*). Araştırmada dikim sıklığının artması ile birlikte dal sayısı ters orantılı olarak değişmiştir.

Tablo 4.Dracocephalum moldavica L. da farklı dikim sıklıkları ve hasat zamanının incelenen verim ve kalite özelliklerin üzerine etkisi

Table 4. The effect of planting density and harvesting time on the traits examined in yield and quality characteristics Dracocephalum moldavica L.

Uygulamalar Treatments	**Bitki Boyu (cm) Plant Height (cm)**			**Dal Sayısı (Adet/bitki) Number of branches (per/plant)**			**Taze Herba Verimi Fresh Weight (kg da^{-1})**		
	40 x25	**60 x25**	**Ortalama Mean**	**40 x25**	**60 x25**	**Ortalama Mean**	**40 x25**	**60 x25**	**Ortalama Mean**
Çiçeklenme öncesi Before Blooming	58.16	57.16	57,91 b	7.33	10.60	9.00	750.39	445.70	598.04 b
Tam Çiçeklenme Full Blooming	64.16	62.00	63,08 a	8.83	13.33	11.00	832.70	628.83	730.76 a
Ortalama Mean	61.16	59.87		8.00 b	12.00 a		791.54 a	537.26 b	
EGF (LSD) %5	Hasat Zamanı (A):3.51 Dikim Sıklığı (B):ö.d. A x B:ö.d			Hasat Zamanı (A):ö.d Dikim Sıklığı (B):2.12 A x B:ö.d			Hasat Zamanı (A):65.84 Dikim Sıklığı (B):69.24 A x B:ö.d		

Dal sayısı üzerine dikim sıklığı x hasat zamanı interaksiyonun etkisi incelendiğinde aralarındaki farklılık önemli olmamakla birlikte, en yüksek değer 13.33 adet/ bitki ile 60x25 cm dikim sıklığında elde edilmiştir. Elde ettiğimiz dal sayısı değerleri Hussein ve ark. (2006)'ın belirttiği sonuçlarla (9.56-12.17 adet/bitki) benzerdir. Bitkiler arasındaki mesafe arttıkça buna paralel olarak dal sayısı da artmıştır. Aynı sonucu Yousefzadeh ve Sabaghnia (2016) Moldovya ejderi' nde farklı dikim sıklığı (10, 15, 20, 40 cm) uyguladıkları çalışmada elde etmişlerdir.

3.3. Taze Herba Verimi

Varyans analizi sonucuna göre, Moldovya ejderi (*Dracocephalum moldavica* L.) bitkisinde hasat zamanı ($P<0.05$) ve dikim sıklığı ($P<0.01$) taze herba verimi üzerinde önemli bir etkiye sahip olduğu; interaksiyonunun ise önemli bir etkiye sahip olmadığı belirlenmiştir (*Tablo 3*). Bitki dikim sıklığı ortalama değerleri incelendiğinde en yüksek taze herba verimi 791,54 kg da^{-1} 40x25 dikim sıklığında elde edilmiştir (*Tablo 4*). Çalışmamızda taze herba verimi bitki sıklığındaki artışla birlikte artmıştır. Taze herba verimi üzerine dikim sıklığı x hasat zamanı interaksiyon etkisi önemli olmamakla birlikte, en yüksek verim değeri 832.70kg da^{-1} olarak tam çiçeklenme döneminde 40x25 dikim sıklığında belirlenmiştir.

Hasat zamanına dair ortalama değerler incelendiğinde en yüksek taze herba verimi 730.76 kg da^{-1} tam çiçeklenme döneminden elde edilmiştir (*Tablo 4*). Çiçeklenme öncesi dönemde yapılan hasatta ise verim değeri 598.04 kg da^{-1} olmuştur. Bitkinin çiçeklenme başlangıcında yapılan hasattan tam çiçeklenme dönemine doğru taze herba veriminde %22 oranında bir artış gözlenmiştir. Bitkinin çiçeklenme döneminde de gelişmesine devam etmesi taze herba ağırlığında artışa neden olmuştur

Khalili ve Armini (2014) Moldovya ejderi' nde aynı sonucu bularak hasat zamanının taze herba verimini etkilediği en yüksek taze herba verimimin tam çiçeklenme döneminde elde edildiğini belirtmişlerdir. Yaptığımız çalışmaya paralel olarak Ahmadi ve Hadipanah (2014) *Dracocephalum moldavica* L.' da bitki sıklığının taze ve kuru herba veriminde etkili olduğunu ve en yüksek taze herba verimini (826.2 kg da^{-1}) en yoğun (30x10) dikim sıklığında elde etmişlerdir. Daha önce farklı tıbbi ve aromatik bitkiler (kekik, oğul otu, limon otu) üzerinde yapılan çalışmamalarda da taze herba verimi bitki yoğunluğunun artışıyla artmıştır (Shalaby ve Razin, 1992; Karık ve Azkan, 2011; Uyanık ve Gürbüz, 2015). Bu durum birim alanda daha fazla sayıda bitki bulunması ve bitkilerin toplamda daha yüksek ışık kullanımı sonucu vejetatif aksamdaki artış ile açıklanabilir (Badi ve ark.,2004). Sonuçlarımız Ahmadi ve Hadipanah (2014) İran koşullarında elde ettiği verim değeriyle (826.2 kg da^{-1}) benzer; Amirnia ve ark., (2015) aynı ekolojik koşullarda elde ettiği verimin (389,23 kg da^{-1}) çok üzerindedir. Bu durum bitki herba verimi üzerinde ekolojik koşulların yanı sıra ekim zamanı, hasat zamanı ve farklı tarımsal uygulamaların da etkisini göstermektedir.

3.4. Drog Herba Verimi

Varyans analizi sonucuna göre, Moldovya ejderi (*Dracocephalum moldavica* L.) bitkisinde hasat zamanı ve dikim sıklığının ($P<0.05$) drog herba verimi üzerinde önemli bir etkiye sahip olduğu; interaksiyonunun ise önemli bir etkiye sahip olmadığı belirlenmiştir (*Tablo 3*). Bitki sıklığına ait ortalama değerler incelendiğinde en yüksek drog herba verimi 184.33 kg da^{-1} 40x25 dikim sıklığında elde edilmiştir (*Tablo 5*). Drog herba verimi üzerine interaksiyon etkisinin değerleri incelendiğinde en yüksek drog herba verimi 212.70 kg da^{-1} olarak 40x25 cm dikim sıklığında elde edilmiştir. Denemede taze herba veriminde olduğu gibi drog herba verimi de birim alanda bitki sayısındaki artış ve azalışa paralel olarak değişmektedir. Farklı iklim koşullarında, farklı bitkiler (*Thymus vulgaris, Origanum onites*) üzerinde yapılan bitki sıklığı çalışmalarında aynı sonuç elde edilmiş, birim alandaki bitki sayısındaki artışa paralel olarak drog herba verimi de arttırmıştır (Badi ve ark., 2004; Kaçar ve ark., 2006). Çalışmamızda hasat zamanının ortalama değerleri incelendiğinde en yüksek drog herba verimi 194.41kg da^{-1} yeşil herba verimin de olduğu gibi tam çiçeklenme döneminde elde edilmiştir (*Tablo 5*). Drog herba verimi değerleri, taze herbanın farklı yöntemlerle kurutulmasıyla elde edilir. Bu iki değer kurutma yöntemine, kurutma süresine gibi çeşitli unsurlara bağlı olarak birbirini oransal olarak etkiler (Polatcı ve Tarhan 2009; Çalişkan ve ark., 2017; Katar ve ark., 2021). Çalışmamızda elde ettiğimiz drog herba verileri Abdossi ve ark. (2015) İran koşullarında elde ettikleri değer (278.75 kg da^{-1}) ile Hussein ve ark. (2006)'nın Mısır koşullarında bildirdiği (185.20 kg da^{-1}) değer arasında yer almaktadır.

3.5. Drog Yaprak Verimi

Varyans analizi sonucuna göre, Moldovya ejderi (*Dracocephalum moldavica* L.) bitkisinde hasat zamanı ve dikim sıklığının ($P<0.05$) drog yaprak verimi üzerinde önemli bir etkiye sahip olduğu, interaksiyonunun ise önemli bir etkiye sahip olmadığı belirlenmiştir (*Tablo 3*). Hasat zamanına ait ortalama değerler incelendiğinde en yüksek drog yaprak verimi tam çiçeklenme döneminde (122.23 kg da^{-1}) elde edilmiştir (*Tablo 5*). Drog yaprak verimi tam çiçeklenme dönemine doğru bitkinin dal sayısındaki artışa ve yeşil aksamındaki gelişmeye paralel olarak artış göstermiştir. Çalışmamızda bitki sıklığı arttıkça taze herba verimin de olduğu gibi drog yaprak verimi de artmıştır.

En yüksek drog yaprak verimi 40 cm dikim sıklığında 106.90 kg da^{-1} olarak bulunmuştur (*Tablo 5*). Bitki sıklığı arttıkça yani toprak yüzeyinde birim alan başına düşen bitki sayısı arttıkça, fotosentez yapılan yüzey alanını artar ve sonucunda drog yaprak veriminde de artış görülür. Farklı bitkilerde yapılan dikim sıklığı çalışmalarında da benzer şekilde, en yüksek yaprak verimi en yoğun dikim sıklıklarında elde edilmiştir (Kızıl ve Tonçer, 2001; Katar ve Gürbüz, 2008).

Drog yaprak verimi üzerine hasat zamanı ve bitki sıklığı interaksiyonun ortalama verileri incelendiğinde en yüksek verim 135.33 kg da^{-1} tam çiçeklenme döneminde 40x25 cm dikim sıklığında elde edilmiştir. Drog yaprak verimi değerleri taze herba verimine paralel bir şekilde artış göstermiştir. Kuru yaprak veriminin, herba verimi, kuru madde oranı ve yaprak oranına bağlı olarak değiştiği bilinmektedir (Ekren ve ark., 2009).

Tablo 5. Dracocephalum moldavica L.' da farklı hasat zamanı ve ekim sıklıklarının incelenen verim ve kalite özelliklerin üzerine etkisi

Table 5. The effect of harvesting time and planting density on the traits examined in yield and quality characteristics Dracocephalum moldavica L.

Uygulamalar Treatments	Drog Herba Verimi Dry Weight (kg da^{-1})			Drog Yaprak Verimi Dry Leaf Weight (kg da^{-1})			Uçucu Yağ Oranı Essential Oil Ratio (%)		
	40 x25	60 x25	Ortalama Mean	40 x25	60 x25	Ortalama Mean	40 x25	60 x25	Ortalama Mean
Çiçeklenme öncesi Before Blooming	155.96	92.13	124.05 b	78.46	52.26	65.36 b	0.27	0.28	0.276 b
Tam Çiçeklenme Full Blooming	212.70	172.13	194.41 a	135.33	109.13	122.23 a	0.36	0.38	0.375 a
Ortalama Mean	184.33 a	132.13 b		106.90 a	80.70 b		0.318	0.333	
EGF %5 LSD	Hasat Zamanı (A):34.86 Dikim Sıklığı (B):32.30 A x B:ö.d			Hasat Zamanı (A):27.28 Dikim Sıklığı (B):23.35 A x B:ö.d			EGF Hasat Zamanı (A):0.0013 EGF Dikim Sıklığı (B):ö.d EGF A x B:ö.d		

3.6. Uçucu Yağ Oranı

Varyans analizi sonucuna göre, Moldovya ejderi (*Dracocephalum moldavica* L.) bitkisinde hasat zamanının ($P<0.01$) uçucu yağ oranı üzerinde önemli bir etkiye sahip olduğu; bitki sıklığı ve interaksiyonunun ise önemli bir etkiye sahip olmadığı belirlenmiştir (*Tablo 3*). Araştırmada bitki sıklığı ortalama değerleri incelendiğinde uçucu yağ oranı 40x25 dikim sıklığında %0.318 bulunurken, 60x25 dikim sıklığında %0.333 e çıkmıştır (*Tablo 5*). Çalışmamızda hasat zamanının ortalama değerleri incelendiğinde uçucu yağ oranı çiçeklenme öncesi 0.276 iken tam çiçeklenme sırasında %0.375 ulaşarak önemli bir artış göstermiştir (*Tablo 5*). Çalışmada hasat zamanı x bitki sıklığı interaksiyon değerleri incelendiğinde, aralarındaki farklılık önemli olmamakla birlikte, en yüksek uçucu yağ oranı %0.38 olarak tam çiçeklenme döneminde 60x45 dikim sıklığına belirlenmiştir. Khalili ve Amirnia (2014) yaptıkları çalışmada Moldovya ejderi'nde en yüksek uçucu yağ oranını çalışmamızla aynı şekilde tam çiçeklenme döneminde bulunduğunu bildirmişlerdir. Said-Al Ahl ve ark. (2015) bitkinin uçucu yağ oranı ve içeriği acısından en büyük etkenin hasat tarihi olduğu belirtmişler ve en yüksek uçucu yağ oranını Mısır koşullarında Mart ayında elde etmişlerdir. Omidbaigi ve ark. (2009) ise İran koşullarında yaptıkları çalışmada en yüksek yağ oranını (%3.2) tam çiçeklenme döneminde elde etmişlerdir. Yapılan bu çalışmalar Moldovya ejderinde bitkinin fenolojik dönemlerinin uçucu yağ oranı üzerinde önemli bir etkisi olduğunu göstermiştir.

Araştırma sonuçları incelendiğinde bitki sıklığındaki artış uçucu yağ oranında azalışa sebep olmuştur. Bitkiler arasındaki mesafenin artmasıyla birlikte bitki bünyesine topraktan daha bol besin elementi ve su alımı sağlanır. Aynı zamanda bitkinin güneş ışığından daha etkin bir şekilde yararlanmasıyla birlikle bitkide daha fazla sekonder metabolit birikimine sağlanmış olur (Khorshidi ve ark., 2009). Daha önce farklı bitkiler (*Satureja khuzestanica, Artemisia annua*) üzerinde yapılan dikim sıklığı çalışmalarında araştırmacılar aynı sonuca ulaşmışlardır (Hadian ve ark., 2016; Nigussie ve ark., 2017).

Bitkinin uçucu yağ oranını Said-Al Ahl ve ark. (2015) Mısır'da %0.11, Shuge ve ark. (2010) Çin'de %0.15; İran'da Ehsani ve ark. (2017) %1, Janmohammadi ve ark. (2014) %0.77, Abdossi ve ark. (2015) %0.065 olarak bulmuşlardır. Bu durumun nedeni bitkinin uçucu yağ oranı üzerinde genotip, ekolojik koşullar, gübreleme, sulama, bitki sıklığı, ekim ve hasat zamanı, farklı kurutma yöntemleri gibi çeşitli unsurların etkisi olmasıdır (Borna ve ark., 2007; Janmohammadi ve ark., 2014; Said-Al Ahl ve ark., 2015; Amirnia ve ark., 2015; Morshedloo ve ark., 2021).

3.7. Uçucu Yağ Bileşenleri

Uçucu yağ bileşen analizi sonucunda *Dracocephalum moldavica* L.'da toplam 42 bileşen belirlenmiştir (*Tablo 6*) Uçucu yağların ana bileşenleri geranil asetat, gerenial (α-citral), neral, geraniol'dur. Bu ana bileşenler uçucu yağın %88.2- 88.9'unu oluşturmaktadır. Araştırmada uçucu yağ ana bileşenlerin toplamının en yüksek oranına (%89.95) tam çiçeklenme döneminde 60x25 cm bitki sıklığında ulaşılmıştır. Geranil asetat, en yüksek değerlerine (%54.72) 40x25 cm dikim sıklığında tam çiçeklenme döneminde ulaşmıştır (*Şekil 1*). Geranil asetat (3,7-dimethylocta-2,6-dien-1-yl ethanoate), uçucu yağlara gül kokusu veren ve bu nedenle parfümeri üretimi için yaygın olarak tercih edilen oksijenli monoterpendir (Rosa ve ark., 2017). Çalışmamızda elde ettiğimiz geranil asetat oranı Omidbaigi ve ark. (2009) % 50.1 oranıyla benzer, daha önce farklı araştırmacıların yaptığı birçok çalışmadan yüksek bulunmuştur (Arabbaghı ve ark., 2014; Janmohammadi ve ark., 2014; Said-Ah Ahl ve ark., 2015; Ehsani ve ark., 2017). Bu durum bitkinin Çukurova koşullarında doğal bir geranil asetat kaynağı olarak kullanılabileceğini düşündürmektedir. Gerenial, neral uçucu bileşenleri geraniol'ün oksidasyon ürünleridir ve genellikle uçucu yağ bileşenlerinde birlikte bulunurlar. (Younis ve ark., 2021). Çalışmamızda da bu üç bileşen birlikte bulunmuş. Tam çiçeklenme döneminde 60x25cm dikim sıklığında gerenial ve neral en yüksek değerleri (sırasıyla %17.396-12.661) geraniol'ün ise en düşük değeri (%5.780) belirlenmiştir

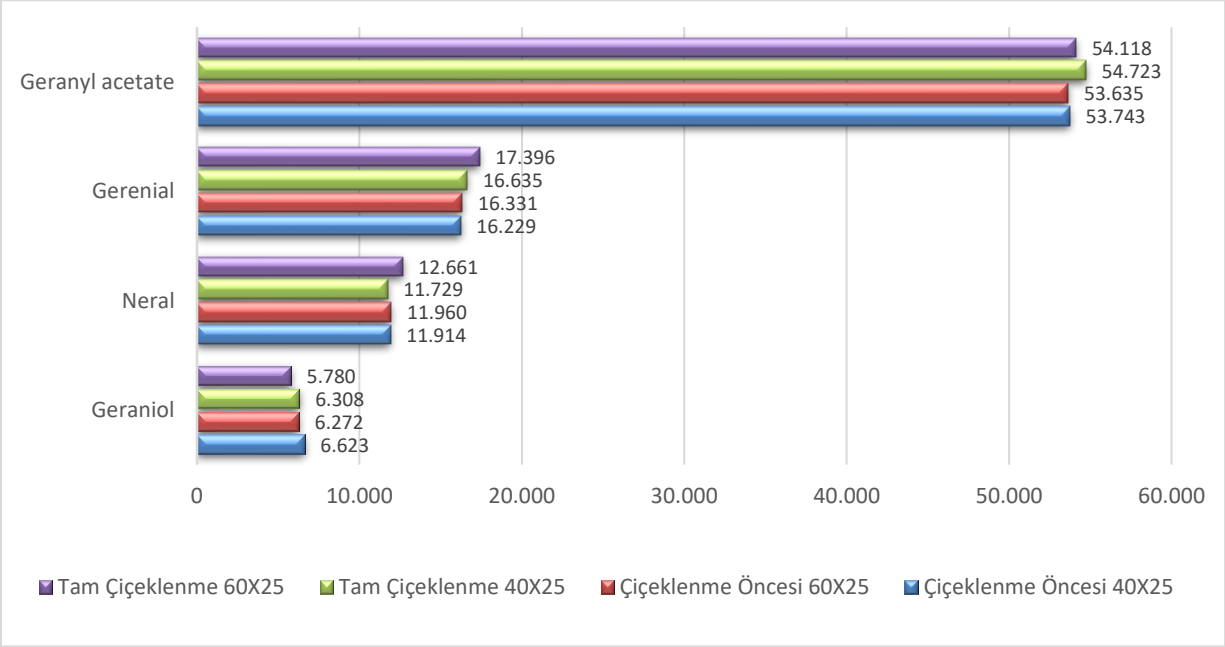

Figure 1. The effect of different planting density and harvest times on essential oil major components in Dracocephalum moldavica L.

Şekil 1. Dracocephalum moldavica L.'da uçucu yağ ana bileşenleri üzerine farklı dikim sıklıkları ve hasat zamanı etkisi

Alaei ve Mahna (2013) İran'da arazi ve sera koşullarında yetiştirdikleri bitkileri kıyasladıkları çalışmalarında uçucu yağın ana bileşenlerini benzer oranlarda sırasıyla toplam %76.8 – 88.5 geranil asetat, gerenial, neral. geraniol olarak bulmuşlardır. Daha önce farklı araştırmacılar tarafından yapılan çalışmalarda bitkinin uçucu yağ ana bileşenlerini çalışmamızla aynı bileşenleri bulmuşlardır (Janmohammadi ve ark., 2014; Said-Al Ahl ve ark., 2015; Amini ve ark., 2020). İran'ın beş farklı bölgesinden topladıkları Moldovya ejderi bitkisini karşılaştıran Yousefzadeh ve ark. (2018) ana bileşenleri geraniol, geranial, and geranil asetat olarak bulmuşlardır. Bu çalışmaların yanı sıra Hussein ve ark. (2006) Mısır'da, Shatar ve Altantsetseg (2000) Finlandiya'da yaptıkları çalışmalarda bitkinin uçucu yağ ana bileşenlerini linalol ve geranial olarak bulmuşlardır. Yapılan çalışmalardan çok farklı olarak Çin'de uçucu yağ ana bileşenleri 1,8-cineol, terpineol-4 ol (%22.82), cumin alcohol (%4.29) olarak bulunmuştur (Chu ve ark., 2011). Tıbbi ve aromatik bitkilerde uçucu yağ içeriğini çevre faktörleri, coğrafi, iklim, edafik, orografik ve biyolojik faktörlerden etkilenebildiği görülmektedir (Maral ve ark., 2015; Baydar, 2016, Soltanbeigi ve Özgüven, 2021).

Tablo 6: Dracocephalum moldavica L.'da uçucu yağ bileşenleri üzerine farklı dikim sıklıkları ve hasat zamanının etkisi

Table 6: The effects of different planting density and harvest times on essential oil components in Dracocephalum moldavica L.

Bileşenler Compounds (%)	**RT**	**Çiçeklenme Öncesi Before Blooming**		**Tam Çiçeklenme Full Blooming**	
		40 cm	**60cm**	**40cm**	**60cm**
beta.-Myrcene	12.65158	0.081	0.067	0.070	0.075
3-Octanone	16.22155	0.135	0.134	0.117	0.124
5-Hepten-2-one. 6-methyl-	19.60732	0.307	0.361	0.311	0.309
1-Octen-1-ol. acetate	21.46133	0.084	0.085	-	-
Rosefuran	22.3607	0.114	0.108	0.142	0.060
4-(2.2-Dimethyl-6-methylenecyclohexyl)butanal	23.1066	0.071	0.074	0.099	0.128
cis-Linalool oxide	24.12875	0.065	0.126	0.106	0.111
1-Octen-3-ol	24.3958	0.234	0.275	0.193	0.105
trans-Linalool oxide	25.2829	0.090	0.129	0.126	0.208
2-Nonyn-1-ol	25.70957	0.080	0.068	0.082	0.124
alfa.-Copaene	26.46467	0.303	0.359	0.224	0.080
trans-Chrysanthemal	26.71637	0.203	0.179	0.251	0.232
Camphor	27.06628	0.195	0.104	0.104	0.253
(-)-.beta.-Bourbonene	27.55433	0.113	0.139	0.113	0.108
Isoneral	28.13447	0.236	0.237	0.212	0.091
Linalool	28.34012	0.713	0.742	0.570	0.264
Isogeranial	29.2416	0.562	0.595	0.519	0.651
Rose furan oxide	30.4826	0.147	0.155	0.288	0.574
Caryophyllene	30.58388	0.247	0.059	0.198	0.229
Z.Z-6.28-Heptatriactontadien-2-one	32.58825	0.154	0.210	0.075	0.060
Neral	**33.4637**	**11.914**	**11.960**	**11.729**	**12.661**
Methyl nerolate	34.0585	0.245	0.125	0.198	0.197
Germacrene D	34.8105	0.193	0.316	0.123	0.134
2-Decyn-1-ol	34.9701	0.082	0.090	0.116	0.114
Nerol acetate	35.22178	3.869	3.579	3.744	3.629
Gerenial	**35.3507**	**16.229**	**16.331**	**16.635**	**17.396**
Geranyl acetate	**36.42497**	**53.743**	**53.635**	**54.723**	**54.118**
β-copaene	36.64288	0.166	0.060	0.062	0.202
Methyl salicylate	36.76873	0.111	0.060	-	-
cis-Geraniol	37.86757	0.177	0.175	0.247	-
Geraniol	**39.51582**	**6.623**	**6.272**	**6.308**	**5.780**
Geranyl acetate. 2.3-epoxy-	43.62573	0.060	0.541	0.067	0.055
Caryophyllene oxide	44.2887	0.437	0.220	0.266	0.278
2-Octen-1-ol. 3.7-dimethyl-. isobutyrate. (Z)-	45.85098	0.224	0.131	0.273	0.061
Levoverbenone	46.42187	-	-	0.078	0.058
Cubenol	46.70427	0.115	0.182	0.063	0.098
(-)-Spathulenol	48.68092	0.159	0.262	0.095	0.062
Hexahydrofarnesyl acetone	48.93875	0.223	0.152	0.081	0.095
Widdrol	52.17072	0.117	0.103	0.146	-
Neric acid	53.84655	0.088	0.328	0.086	0.109
Geranic acid	55.10188	0.269	0.058	0.248	-
Phenylephrine	56.09023	0.096	0.071	0.172	-
Geranyl acetate+ Gerenial +Neral + Geraniol		88.509	88.203	89.395	89.955
Toplam		99.546	98.857	99.26	98.833

4. Sonuç

Türkiye'de Moldovya ejderi bitkisi üzerine yapılan verim ve kalite bileşenlerinin birlikte incelendiği çalışma bulunmamaktadır. Bitkinin Çukurova koşullarında yetiştiriciliği başarıyla yapılmıştır. Bitkinin verim ve kalite değerleri daha önce farklı coğrafyalarda yapılan çalışmalarla benzer veya yüksektir. Bununla birlikte bitkinin uçucu yağ bileşenleri incelendiğinde Geranil asetat değerleri (%53.635-54.118) daha önce farklı araştırmacıların yaptığı çalışmalardan yüksek bulunmasıyla dikkat çekmektedir. Çukurova koşulları için bitkinin hasatının, verim komponentlerinin artış gösterdiği tam çiçeklenme döneminde yapılması uygun görülmektedir. Bitki dikim sıklığı arttıkça taze herba, drog yaprak ve herba verimi artmıştır. Elde ettiğimiz veriler doğrultusunda Çukurova koşullarında Moldovya ejderi için en uygun hasat zamanı tam çiçeklenme dönemi, en uygun bitki dikim sıklığı ise 40×25 cm olarak tavsiye edilmektedir.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Bayburt İli Fasulye Ekim Alanlarında Görülen Yabancı Otlar, Yoğunlukları ve Rastlama Sıklıkları*

Determination of the Weed Species, Density and Frequency in Bean Fields in Bayburt Province

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Öz

Bu çalışma Bayburt İli fasulye ekim alanlarındaki yabancı otların tespiti, yoğunlukları ve rastlama sıklıkları durumlarının belirlenmesi amacıyla 2020 yılında Bayburt Merkez, Aydıntepe ve Demirözü ilçelerinde yürütülmüştür. Çalışma yapılacak alanın çevresindeki ürün deseni göz önüne alınarak, farklı ürün desenlerinin bulunduğu bölgelerde çalışmalar alanın iç kesimlerinde 1 m²'lik çerçeveler kullanılarak yapılmıştır. Çerçeve içerisine denk gelen her bir yabancı ot için sayımlar yapılmıştır. Yapılan incelemeler sonucunda 1 tek çenekli (Monocotyledoneae) ve 15 çift çenekli (Dicotyledoneae) olmak üzere 16 familyaya ait 26 cinse mensup 26 yabancı ot türü belirlenmiştir. Bu yabancı otların yoğunluklarının 0.02 ile 5.29 bitki m^{-2} arasında değiştiği ve ortalama yoğunluğun ise 18.98 bitki m^{-2} olduğu tespit edilmiştir. Bayburt il bazında yapılan sürvey çalışmaları sonucu ortalama yoğunluk ve rastlama sıklığı bakımından en fazla türler sırasıyla *Elymus repens* (L.) Gould (5.29 bitki m^{-2}; %68.46), *Amaranthus retroflexus* L. (4.50 bitki m^{-2}; %66.65), *Convolvulus arvensis* L. (3.16 bitki m^{-2}; %62.92), *Chenopodium album* L. (0.87 bitki m^{-2}; %31.86) ve *Cirsium arvense* (L.) Scop. (0.82 bitki m^{-2}; %31.79) olup en az türler ise sırasıyla *Setaria viridis* (L.) P. Beauv. (0.07 bitki m^{-2}; %5.67), *Ranunculus arvensis* L. (0.07 bitki m^{-2}; %4.76), *Chondrilla juncea* L. (0.07 bitki m^{-2}; %3.89), *Vicia cracca* L. (0.06 bitki m^{-2}; %5.56), *Boreava orientalis* Jaub. and Spach (0.04 bitki m^{-2}; %3.43) ve *Isatis glauca* Aucher ex Boiss. (0.02 bitki m^{-2}; %1.54) olarak belirlenmiştir. Bayburt ili fasulye tarlalarında, birim alandan elde edilecek verimin artırılması için özellikle *Elymus repens* (L.) Gould, *Amaranthus retroflexus* L. ve *Convolvulus arvensis* L. gibi yabancı otlarla mücadele yapılması gerekmektedir. Bunun için yöreye adapte olmuş fasulye çeşitlerine önem verilmelidir.

Anahtar Kelimeler: Fasulye, Yabancı ot, Yabancı ot yoğunluğu, Rastlama sıklığı, Bayburt

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Abstract

This study was carried out in Bayburt Merkez, Aydıntepe and Demirözü districts in 2020 in order to determine the weeds, their densities and their incidence in the bean cultivation areas of Bayburt Province. Considering the product pattern around the area to be studied, studies were carried out in areas with different product patterns, using 1 m² frames in the inner parts of the area. Counts were made for each weed in the frame. As a result of the examinations, 26 weed species belonging to 26 genera belonging to 16 families, 1 from Monocotyledoneae and 15 from the Dicotyledoneae, were determined. It has been determined that the densities of these weeds vary between 0.02 and 5.29 plant m^{-2} and the average density is 18.98 plant m^{-2}. As a result of the survey studies conducted on the basis of Bayburt province, the highest species in terms of average density and frequency of occurrence were *Elymus repens* (L.) Gould (5.29 plant m^{-2}; 68.46%), *Amaranthus retroflexus* L. (4.50 plant m^{-2}; 66.65%), *Convolvulus arvensis* L. (3.16 plant m^{-2}; 62.92%), *Chenopodium album* L. (0.87 plant m^{-2}; 31.86%) and *Cirsium arvense* (L.) Scop. (0.82 plant m^{-2}; 31.79%) and the least species were *Setaria viridis* (L.) P. Beauv. (0.07 plant m^{-2}; 5.67%), *Ranunculus arvensis* L. (0.07 plant m^{-2}; 4.76%), *Chondrilla juncea* L. (0.07 plant m^{-2}; 3.89%), *Vicia cracca* L. (0.06 plant m^{-2}; 5.56%), *Boreava orientalis* Jaub. and Spach (0.04 plant m^{-2}; 3.43%) and *Isatis glauca* Aucher ex Boiss. (0.02 plant m^{-2}; 1.54%). In the bean fields of Bayburt province, it is necessary to control weeds such as *Elymus repens* (L.) Gould, *Amaranthus retroflexus* L. and *Convolvulus arvensis* L. in order to increase the yield to be obtained from the unit area. For this, attention should be paid to bean varieties adapted to the region.

Keywords: Bean, Weed, Weed density, Frequency, Bayburt

1. Giriş

İnsanoğlunun yeryüzündeki hayatının sürekliliği için diğer tüm organizmaların korunması ve yaşamalarına devam etmesi gerekmektedir. İşte bu canlıların içinde yabancı otlar oldukça büyük önem arz etmektedir (Çoruh ve ark., 2014).

Dünyada üretimi yapılan baklagiller içerisinde sırasıyla fasulye, nohut, bezelye, börülce, mercimek ve bakla önde gelmektedir (Anonim, 2015). Güney Amerika fasulyenin anavatanı olup, ülkemizin hemen hemen tüm bölgelerinde yetişebilen ve en fazla üretimi yapılan sebze türlerinden birisidir. Taze fasulye A, B1, B2 ve C vitaminlerince zengindir. Fasulye bir sıcak iklim bitkisidir. Fasulye bitkisi tohumu 15-20 °C'de çimlenebilen, pH'sı 7-8 olan tınlı, alkali ve tuzluluk sorunu olmayan verimli topraklarda iyi yetişmektedir (Anonim, 2021a).

Fasulye bitkisinin verimini artırmak için iyi bir toprak hazırlığı, uygun sulama, yeterli ve dengeli gübreleme gibi kültürel uygulamaların yanında, yabancı otlarla mücadelenin de yapılması zorunludur. Yabancı otlar sebebiyle fasulye bitkisinde önemli verim kayıplarının olduğu bilinmektedir. Bu kayıplar yabancı otların türüne ve yoğunluğuna bağlı olarak değişmektedir (Zengin, 1999).

Yabancı otlar kültür bitkileri ile büyüme faktörleri olan besin maddeleri, su ve ışık yönünden rekabete girerek verim kayıplarına neden olmaktadır (Özer ve ark., 2001; Tepe, 2014; Güncan, 2019). Fasulye bitkisinde yabancı ot türlerinden dolayı, önemli derecede ürün kayıplarının ortaya çıktığı bilinmektedir. Nitekim Cramer (1967) Amerika Birleşik Devletleri'nde yabancı otların fasulyede %8.7 oranında ürün kaybına neden olduklarını bildirmektedir. Fasulyedeki ürün kaybında, kültür bitkisi ile yabancı ot türü ve yoğunluğu büyük rol oynamaktadır. Yabancı otlardan dolayı fasulye bitkisinde meydana gelen zarar, bitkinin çıkıştan sonraki ilk 4-6 haftalar içerisinde en yüksek seviyesinde olmaktadır (Nieto ve ark., 1968). Fasulye çeşitleri arasında da yabancı otlarla rekabet açısından farklılıklar bulunmaktadır. Sırık fasulyede farklı, bodur çeşitlerde farklı yabancı ot türleri sorun oluşturmasının yanında, tarlaya ekildiğinde veya sebze olarak yetiştirildiğinde de farklı türler ortaya çıkabilir (Tepe, 2014).

Ülkemiz genelinde fasulyenin 2020 yılı ekim alanı, üretimi ve verimi sırasıyla kuru fasulyede 1.029.850 da, 279.518 ton ve 271 kg da^{-1}; taze fasulyede ise 415.110 da, 547.349 ton ve 1.319 kg da^{-1} olduğu belirlenmiştir. Buradan fasulyenin insan gıdası olarak tüketimine yönelik yetiştiriciliğinin, ekim alanı, üretimi ve verimi sırasıyla kuru fasulyede 2.516 da, 302 ton ve 120 kg da^{-1}, taze fasulyede 482 da, 578 ton ve 1.200 kg da^{-1} ile Bayburt ili ön plana çıkmıştır (Anonim, 2021b).

Bayburt ili (Merkez, Aydıntepe ve Demirözü) fasulye yetiştiriciliği yapılan ekili alanlarda yabancı otlarla mücadele teknikleri üreticilerimiz tarafından gereği gibi uygulanmadığından dolayı ürün kayıpları meydana gelmektedir. Bu durum fasulye bitkisinde yabancı ot mücadelesinin son derece önemli olduğunu ve mücadelenin gerekliliğini ortaya koymaktadır. Yabancı otlara karşı etkili bir mücadelenin yapılabilmesi için öncelikle fasulye ekim alanlarındaki yabancı ot türlerinin yoğunluk ve rastlama sıklıklarının belirlenmesi gerekmektedir. Bu nedenle Bayburt ili (Merkez, Aydıntepe ve Demirözü) fasulye ekili alanlarındaki yabancı otların türleri, yoğunlukları ve rastlama sıklıklarının tespit edilmesi amaçlanmıştır.

2. Materyal ve Metot

Çalışmadaki ana materyal, Bayburt Merkez, Aydıntepe ve Demirözü ilçelerinde fasulye ekim alanlarındaki yabancı otlardır (*Şekil 1*).

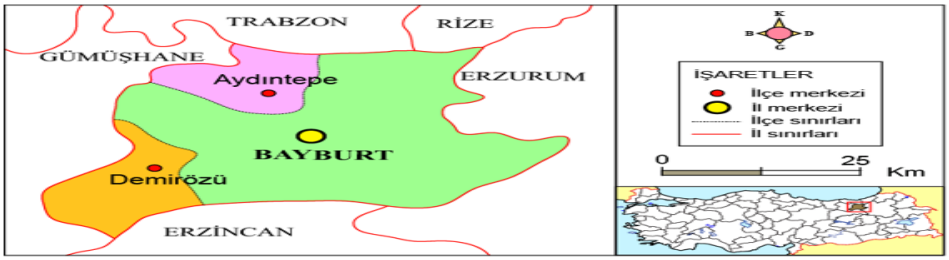

Figure 1. Bayburt province geographical map

Şekil 1. Bayburt ili coğrafi haritası

2.1. Sürvey Çalışmaları

Sürvey çalışmaları, Bayburt ilinin Merkez, Aydıntepe ve Demirözü ilçelerinde 2020 vejetasyon döneminde gerçekleştirilmiştir (*Tablo 1*).

Tablo 1. 2020 Bayburt İli Fasulye Üretim Verileri (Anonim, 2021b)

Table 1. 2020 Bean Production Data for Bayburt Province (Anonim, 2021b)

	Kuru Fasulye *Dry Bean*		**Taze Fasulye** *Green Bean*	
BAYBURT 2020	**Ekim Alanı** *Sowing Area* **(da)**	**Üretim** *Production* **(ton)**	**Ekim Alanı** *Sowing Area* **(da)**	**Üretim** *Production* **(ton)**
Merkez	1900	228	286	343
Demirözü	158	19	125	150
Aydıntepe	458	55	71	85
Genel *Total*	2.516	302	482	578

Sürvey çalışmaları 2020 yılında Bayburt Merkez, Aydıntepe ve Demirözü ilçelerinde bölümlü örnekleme yöntemine göre yapılmıştır (Bora ve Karaca, 1970). Çalışma alanını oluşturan üç ilçede toplam 46 fasulye tarlasına gidilerek örnekleme yapılmıştır. Çalışmalar 2020 yılında fasulye ekim ve hasat tarihlerine bağlı olarak Haziran-Eylül ayları arasında yapılmıştır. Çalışma yapılacak alanın çevresindeki ürün deseni göz önüne alınarak, farklı ürün desenlerinin bulunduğu bölgelerde çalışmalar alanın iç kesimlerinde 1 m²'lik çerçeveler kullanılarak yapılmıştır. Bayburt ili genelinde ekilen fasulye tarlalarının 10 dekardan küçük olması sebebiyle 3 dekarın altına düşmemek kaydıyla her tarlaya 4 çerçeve atılmıştır. Çerçeve içerisine denk gelen her bir yabancı ot için sayımlar yapılmıştır (Odum, 1971). Çerçeve içerisindeki yabancı otların sayımı yapılırken geniş yapraklı yabancı otlar tüm bitki olarak, dar yapraklıların (Poaceae) ise kardeşlenme sayıları sayılarak değerlendirme yapılmış olup sürvey formlarına kaydedilmiştir. Yapılan sayımlar sonucu her bir yabancı ot için aritmetik ortalama alınarak her türe ait yoğunluklar hesaplanmıştır (Güncan, 2019). Çalışma sırasında teşhisi yapılamayan yabancı otlar Davis (1965-1988) ve Atatürk Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü Herbaryumu'ndan yararlanılarak yapılmıştır. Teşhis edilen yabancı otların Türkçe adları Uluğ ve ark. (1993)'den alınmıştır.

2.2. Yoğunluk ve Rastlama Sıklığının Belirlenmesi

Yabancı otların yoğunluklarının belirlenmesinde 1 m²'lik çerçeveler içerisine giren her bir yabancı otun aritmetik ortalamaları hesaplanmıştır. Atılan çerçeveler içerisine giren her bir yabancı ot için sayımlar yapılarak, atılan toplam çerçeve sayısına bölümü sonucu her bir yabancı ot için yoğunluk (bitki m^{-2}) hesaplaması yapılmıştır.

Tespit edilen yabancı otlara ait yoğunluk;

$Yoğunluk = B\ m - 1$ formülü kullanılarak hesaplamalar yapılmıştır (Güncan, 2019).

Formülde;

B: Atılan çerçevelerin içerisine denk gelen her bir yabancı ot türünün toplam sayısı

m: Atılan toplam çerçeve adedi

Rastlama sıklığı (R. S.) ise;

$R.S.(\%) = N\ m - 1\ x\ 100$ formülü kullanılarak hesaplamalar yapılmıştır (Odum, 1971).

Formülde;

N: Yabancı ot türünün tespit edildiği çerçeve adedi

m: Atılan toplam çerçeve adedi

3. Araştırma Sonuçları ve Tartışma

Bayburt ili Merkez, Aydıntepe ve Demirözü ilçelerindeki fasulye ekim alanlarında 1 tek çenekli (Monocotyledoneae) ve 15 çift çenekli (Dicotyledoneae) olmak üzere 16 familyaya ait 26 cinse mensup 26 yabancı ot türü belirlenmiştir. Bu yabancı otların yoğunluklarının 0.02 ile 5.29 bitki m^{-2} arasında değiştiği ve ortalama yoğunluğun ise 18.98 bitki m^{-2} olduğu tespit edilmiştir. Yabancı ot türlerinin familyalara göre dağılımları, Türkçe adları, yoğunlukları ve rastlama sıklıkları *Tablo 2*'de verilmiştir.

Bayburt il bazında yapılan sürvey çalışmaları sonucu ortalama yoğunluk ve rastlama sıklığı bakımından en fazla türler sırasıyla *Elymus repens* (L.) Gould (5.29 bitki m^{-2}; %68.46), *Amaranthus retroflexus* L. (4.50 bitki m^{-2}; %66.65), *Convolvulus arvensis* L. (3.16 bitki m^{-2}; %62.92), *Chenopodium album* L. (0.87 bitki m^{-2}; %31.86) ve *Cirsium arvense* (L.) Scop. (0.82 bitki m^{-2}; %31.79) olup en az türler ise sırasıyla *Setaria viridis* (L.) P. Beauv. (0.07 bitki m^{-2}; %5.67), *Ranunculus arvensis* L. (0.07 bitki m^{-2}; %4.76), *Chondrilla juncea* L. (0.07 bitki m^{-2}; %3.89), *Vicia cracca* L. (0.06 bitki m^{-2}; %5.56), *Boreava orientalis* Jaub. and Spach (0.04 bitki m^{-2}; %3.43) ve *Isatis glauca* Aucher ex Boiss. (0.02 bitki m^{-2}; %1.54) olarak belirlenmiştir (*Tablo 2*).

Dovan ve Güncan (1997) Konya bölgesinde 1995 yılında fasulye bitkisinde yaptıkları çalışma sonucunda, 22 familyaya ait 56 yabancı ot türüne rastlanmış ve en yoğun tür olarak *C. album* (sirken), *A. retroflexus* (kırmızı köklü tilki kuyruğu), *C. arvensis* (tarla sarmaşığı), *Amaranthus albus* L. (horozibiği), *Sinapis arvensis* L. (yabani hardal), *Salsola ruthenica* Iljin. (soda otu), *Heliotropium dolosum* D. Not. (kederli bozot) ve *C. arvense* (köygöçüren)'nin tespit edildiğini bildirmişlerdir. Çalışmada tespit edilen kırmızı köklü tilkikuyruğu, sirken, tarla sarmaşığı, köygöçüren ve yabani hardalın yoğunluk ve rastlama sıklığı açısından Bayburt'ta yapılan çalışma sonuçları ile benzerlik gösterdiğini ancak diğer türlerle arasında farklılıklar olduğunu söylemek mümkündür.

Erol ve ark. (1997) Tokat Kozova'da 1995 yılı vejetasyon döneminde fasulye ekim alanlarında yapılan sürvey sonucunda 51 yabacı ot türü saptanmıştır. Kozova genelinde en önemli yabancı ot türleri; *A. retroflexus, C. album, C. arvense, S. arvensis, Heliotropium hirsutissumum* Grauer, *Solanum. nigrum* L., *Portulaca oleracea* L., ve *Echinochloa crus-galli* (L.) P. Beauv. olarak bildirmiştir. Bayburt'taki çalışmada da *A. retroflexus, C. album, C. arvense* ve *S. arvensis* fasulye ekim alanlarında hem yoğunluk hem de rastlama sıklığı açısından benzer olduğu görülmüştür.

Kadıoğlu ve ark. (1997) Akdeniz Bölgesindeki Adana, Antalya, Gaziantep, Kahramanmaraş ve İçel illerindeki yemeklik tane baklagillerden nohut ve fasulye tarlalarında ki yabancı otların yoğunluk ve yaygınlıklarını belirlemişlerdir. Bu çalışmada, nohut tarlalarında Adana'da *C. arvensis, Chondrilla juncea* L., *Centaurea cyanus* L.; Antalya'da *Salvia syriaca* L., *Avena sterilis* L., *Tragopogon* spp.; Gaziantep'te *A. sterilis, Chrozophora tinctoria* (L.) Rafin., *Euphorbia* spp.; İçel'de *C. album, C. juncea, Galium aparine* L.; Kahramanmaraş'ta *S. arvensis, Scandix pecten-veneris* L., *Chenopodium* spp. yoğunluk ve yaygınlık bakımından en fazla yabancı ot türleri olarak belirlenmiştir. Fasulye tarlalarında ise Adana'da *Amaranthus chlorostachys* Willd., *Beckmannia eruciformis* (L.) Host.; Kahramanmaraş'ta *C. album, A. chlorostachys, Hibiscus trionum* L.; Antalya'da *C. album, H. trionum, P. oleracea* en yoğun yabancı ot türleri olarak tespit edilmiştir. Yapılan çalışma incelendiğinde yoğunluk ve yaygınlık olarak tespit edilen yabancı otlar, Bayburt ilindeki çalışmada bazı bitki türleri ile paralellik gösterdiği belirlenmiştir.

Zengin (1998) tarafından Erzincan şartlarında 1997 yılında 20 fasulye tarlasında yapılan örnekleme çalışmasında, fasulye ekim alanlarında görülen yabancı otlar ve dağılımı tespit edilmiştir. Yapılan çalışmada 13 familyaya ait 27 yabancı ot türü belirlenmiş olup bunlardan; *Cynodon dactylon* Pers., *S. nigrum, H. trionum, A. retroflexus* ve *E. crusgalli*'nin en önemli türler olduğunu bildirmiştir. Bayburt ili ve yakın çevre illerdeki fasulye ekim alanlarında başlıca sorun oluşturan yabancı ot türleri arasında *A. retroflexus*'un birçok çalışmada yaygın olduğu görülmüştür.

Zengin (1999) Erzurum şartlarında fasulye ekim alanlarında 1990 ve 1995 yıllarında yürütülen çalışmada, *C. arvensis* araştırma alanlarının hepsinde yoğun ve yaygın, *A. retroflexus* ise sadece yoğun olarak tespit edilmiştir. Aşkale'de topluluğun esas üyesini *C. arvensis* ve *S. arvensis*, Pasinler ve Tortum'da *C. album* oluşturduğunu bildirmektedir. Fasulye ekim alanlarında yoğunluk ve yaygınlık açısından ismi geçen yabancı ot türlerinin Bayburt ilinde de bulunduğu görülmektedir.

Tablo 2. Bayburt İli Fasulye Ekim Alanlarında Görülen Yabancı Otlar, Yoğunlukları ve Rastlama Sıklıkları

Table 2. Determination of the Weed Species, Density and Frequency in Bean Fields in Bayburt Province

Yabancı Ot Türleri ve Familyaları ***Weed Species and Families***	**Yoğunluk** ***Density*** **(bitki m^{-2})** **(*plant m^{-2}*)**	**Rastlama Sıklığı** ***Frequency*** **(%)**
AMARANTHACEAE		
Amaranthus retroflexus L. (Kırmızı köklü tilki kuyruğu)	4.50	66.65
ASTERACEAE		
Artemisia absinthium L. (Acı pelin)	0.23	12.33
Chondrilla juncea L. (Akhindiba)	0.07	3.89
Cirsium arvense (L.) Scop. (Köygöçüren)	0.82	31.79
Xanthium strumarium L. (Domuz pıtrağı)	0.58	26.64
BRASSICACEAE		
Boreava orientalis Jaub. and Spach (Sarıot)	0.04	3.43
Capsella bursa-pastoris (L.) Medik. (Çoban çantası)	0.08	5.00
Isatis glauca Aucher ex Boiss.(Gri çivit otu)	0.02	1.54
Sinapis arvensis L. (Yabani hardal)	0.39	19.72
CHENOPODIACEAE		
Chenopodium album L. (Sirken)	0.87	31.86
CONVOLVULACEAE		
Convolvulus arvensis L. (Tarla sarmaşığı)	3.16	62.92
EUPHORBIACEAE		
Euphorbia virgata Waldst. et Kit. (Çubuksu sütleğen)	0.17	10.74
FABACEAE		
Vicia cracca L. (Kuş fiği)	0.06	5.56
FUMARIACEAE		
Fumaria officinalis L. (Hakiki şahtere)	0.12	8.17
GERANIACEAE		
Geranium rotundifolium L. (Değirmi Yapraklı Jeranyum)	0.42	24.72
MALVACEAE		
Hibiscus trionum L. (Yabani bamya)	0.20	11.50
POACEAE		
Avena fatua L.(Yabani yulaf)	0.09	7.14
Cynodon dactylon (L.) Pers. (Köpek dişi ayrığı)	0.61	23.87
Echinochloa crus-galli (L.) P. Beauv. (Darıcan)	0.40	22.22
Elymus repens (L.) Gould. (Ayrık)	5.29	68.46
Setaria viridis (L.) P. Beauv. (Yeşil kirpi darı)	0.07	5.67
RANUNCULACEAE		
Ranunculus arvensis L. (Tarla düğün çiçeği)	0.07	4.76
RESEDACEAE		
Reseda lutea L. (Muhabbet çiçeği)	0.08	4.82
RUBIACEAE		
Galium tricornutum Dandy (Boynuzlu yoğurt otu)	0.43	21.33
SCROPHULARIACEAE		
Linaria kurdica Boiss. et Hohen. (Nevruz otu)	0.08	4.82
SOLANACEAE		
Solanum nigrum L. (Köpek üzümü)	0.13	8.19
Genel Ortalama *Total*	18.98	

Saltabaş ve Zengin (2001) tarafından Erzincan (Merkez, Üzümlü ve Çayırlı) ilinde fasulye ekili alanlarında yoğun ve yaygın olarak bulunan yabancı ot türleri üzerine yapılan çalışmada; *H. trionum* (yabani bamya), *C. dactylon* (köpek dişi ayrığı), *A. retroflexus* (kırmızı köklü tilki kuyruğu), *E. crus-galli* (darıcan), *S. nigrum* (köpek

üzümü*), C. arvensis* (tarla sarmaşığı), *C. album* (sirken), *X. strumarium* (domuz pıtrağı), *C. juncea* (akhindiba) ve *A. graveolens* (dereotu)'nun yabancı ot türlerinin olduğunu bildirmişlerdir. Her iki çalışmanın en önemli ortak tarafı yoğunluk olarak *A. retroflexus C. arvensis* ve *C. album*'un her iki ilde de aynı bitkilerin olmasıdır.

Tepe ve ark. (2002) Van'daki mercimek ekili alanlarda bulunan yabancı otlardan *Hordeum vulgare* L., *Heliotropium europaeum* L., *C. dactylon, C. arvensis, Centaurea depressa* Bieb., *Adonis aestivalis* L., *Acroptilon repens* (L.) DC. ve *Euphorbia heteradena* Jaub. et Spach'nın en yoğun türler olduğunu tespit etmişlerdir. Her iki çalışmada belirlenen *C. arvensis* ve *C. dactylon* bitkilerinin ortak olmasıdır.

Eroğlu (2006) Karaman ilinde nohut tarlalarında bulunan 17 yabancı otun içerisinde bulunan sirken (*C. album*), tarla sarmaşığı (*C. arvensis*), horoz ibiği (*A. retroflexus*), kıvırcık labada (*Rumex crispus* L.) ve yabani hardal (*S. arvensis*)'ın en fazla yoğun türler olduğunu bildirmiştir. Çalışmada kıvırcık labada ve yabani hardal hariç Bayburt ilinde en çok yoğun türler ile benzerlik gösterdiği görülmüştür.

Zengin ve Çoruh (2007) Erzurum ili fasulye ekim alanlarında yabancı ot kontrolü için kritik periyodun belirlenmesi amacıyla yaptıkları çalışmada *A. retroflexus, C. album, C. arvense, C. arvensis* ve *Sideritis montana* L.'nın en yoğun yabancı ot türler olduklarını bildirmişlerdir. *S. montana* hariç, diğer türlerin Bayburt'ta da yüksek olduğu bulunmuştur.

Zengin ve Çoruh (2010) Erzincan İli fasulye ekili alanlarda yabancı ot florası ve yoğunlukları üzerine iki farklı su kaynağı ile sulamanın etkisini belirlemek amacıyla yaptıkları çalışmada; fasulye tarlalarında yabani bamya (*H. trionum*), akkazayağı (*C. album*), horoz ibiği (*A. retroflexus*), semizotu (*P. olarecea*), köpek dişi ayrığı (*C. dactylon*), köpek üzümü (*S. nigrum*), yeşil kirpi darı (*S. viridis*), tarla sarmaşığı (*C. arvensis*) ve darıcan (*E. crus-galli*)'nın en yoğun türler olduğunu bildirmişlerdir. Bayburt ilinde fasulye tarlalarında *P. olarecea* yabancı ot türü hariç diğer 8 tür hem yoğunluk hem de rastlama sıklığı açısından benzerlik gösterdikleri ortaya konulmuştur.

Göktepe (2016) Uşak iline bağlı Merkez, Banaz, Eşme, Karahallı, Sivaslı ve Ulubey ilçelerinde, nohut ekili alanlarında bulunan yabancı otlar, yoğunlukları ve rastlanma sıklıklarını belirlemek amacıyla yapılan çalışmada; ortalama olarak en yoğun ve yaygın türlerin *C. album C. arvensis, A. sterilis* ve *S. arvensis* olduğu bildirilmiştir. Bayburt ilinde ise *A. sterilis* ve *S. arvensis* hariç diğer türler benzerlik göstermektedir.

Baklagil familyası dışındaki kültür bitkilerinden örneğin Hatay ili havuç ekim alanlarında (Üremiş ve ark., 2020) ve Tekirdağ ili bağ alanlarında (Kara ve Ata, 2021) yabancı ot yoğunlukları ve rastlama sıklıkları ile ilgili yapılan çalışmalarda *A. retroflexus, C. album* ve *C. arvensis*'in en yoğun ve yaygın türler arasında olduklarını bildirmişlerdir. Her iki çalışmada görülen yabancı otlar, Bayburt ilindeki fasulye ekim alanlarında da en yoğun ve yaygın türler arasında oldukları tespit edilmişlerdir.

4. Sonuç

Bayburt ili fasulye ekim alanlarında tespit edilen yabancı ot türleri, Türkiye'deki diğer illerle kıyaslandığında büyük oranlarda benzer gösterdiği ve tespit edilen türlerin yoğunluk ve rastlama sıklıkları açısından yıldan yıla ve bölgeden bölgeye göre farklılıklar görülmektedir. Bu türler arasında hem yoğunluk hem de rastlama sıklığı bakımından en yoğun türler *E. repens, A. retroflexus, C. arvensis, C. album* ve *C. arvense*'dir. Bunun için de yöreye adapte olmuş fasulye çeşitlerine önem verilmesi gerekmektedir. Ayrıca Bayburt ilinde genellikle çiftlik gübresi kullanıldığından gübrenin en az altı ay yanmış olmasına özen gösterilmelidir. Bununla birlikte iyi bir tohum yatağının hazırlanması yanında fasulye bir çapa bitkisi olduğundan, çapalama ile yabancı otlar geniş ölçüde ortadan kaldırılmaktadır. Bu belirtilen kültürel önlemlerle birlikte mekanik mücadelenin yapılması kimyasal mücadeledeki herbisit kullanımını büyük ölçüde azaltacaktır. Böylelikle kimyasal mücadelede çiftçilerimizin gereksiz yere herbisit kullanımının önüne geçilerek doğada meydana gelen kimyasal atıklardan toprağın verimsizleşmesine ve insan sağlığı açısından tehlikeli kimyasal birikmelerin önüne geçilmesi sağlanacaktır.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effects of Plant Growth Regulators on the Usage of *In Vitro* Stem Disc Culture for Mass Seedling Production in Kahramanmaraş Garlic (*Allium sativum* L.)*

Kahramanmaraş Sarımsağında (*Allium sativum* L.) Kitlesel Fide Elde Etmek Amacıyla *In Vitro* Gövde Diski Üretim Tekniğinin Kullanımında Bitki Büyüme Düzenleyicilerinin Etkileri

Ayşe GÜLÇEBİ[1], İrfan Ersin AKINCI[2*]

Abstract

Anatolia is one of the important production areas of garlic. Garlic production is conducted by using the head or the cloves inside the heads, which are actually the consumed part of the garlic, as propagation material. However, due to the use of cloves, which are the most valuable part of the market, as reproduction material, the profit is reduced by about 10%. The study aims to provide an alternative propagation material to reduce the losses resulting from this practice in local Kahramanmaraş garlic production. For this purpose, generating plantlets directly from stem discs of the garlic cloves *in vitro* and the effects of different growth regulators have been studied. For this, the plant growth regulators added to MS media as BAP (1.0, 1.5 and 2.0 mg l^{-1}), GA_3 (0.5, 1.0 and 1.5 mg l^{-1}), 2-IP (0.75, 1.00 and 1.25 mg l^{-1}); kinetin (1.0, 2.0 and 3.0 mg l^{-1}) and TDZ (0.75, 1.00 and 1.25 mg l^{-1}) were tested. In the study number of explants, number of infected explants, number of healthy explants, number of developed explants, healthy explant rate, developed explant rate, number of callused explants, callus growth rate, number of proliferated explants, proliferation rate, proliferation number, number of rooted explants, rooting rate and number of roots were investigated. However, shoot ratios, shoot numbers, and callus formation were the main focus. The highest rates of proliferation were found in 2-IP (53.8%, 45.5%, and 40.0% at 1.00, 0.75, and 1.25 mg l^{-1} dosages, respectively) and Kinetin (35.3% at 2.00 mg l^{-1}). The maximum shoot number was reached with 2-IP at the dose of 1.00 mg l^{-1} as 1.9 shoot/explants. Kinetin at 3.00 mg l^{-1} and 2IP at 1.25 mg l^{-1} were the other successful applications with 1.8 shoots. This study indicated promising results to obtain plantlets directly from the clove's stem discs and including them into seedling production for the mass production of garlic.

Keywords: Stem disc culture, BAP, GA_3, 2-IP, Kinetin, TDZ, Garlic

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Öz

Anadolu sarımsağın önemli üretim alanlarından birisidir. Sarımsak üretimi, sarımsağın tüketilen kısmı olan baş veya başların içindeki dişlerin üretim materyali olarak kullanılmasıyla gerçekleştirilmektedir. Ancak, pazar bakımından en değerli kısmı olan dişlerin üreme materyali olarak kullanılması nedeniyle kazanç yaklaşık %10 oranında azalmaktadır. Araştırmanın amacı Kahramanmaraş yöresel sarımsak üretiminde, dişlerle yapılan üretim sonucu ortaya çıkan kayıpları azaltmak için alternatif çoğaltma materyali sağlanmasıdır. Bu amaçla sarımsak dişlerinin gövde disklerinden in vitro'da doğrudan bitkicik elde edilmesine ve farklı bitki büyüme düzenleyicilerin etkilerine çalışılmıştır. Bunun için MS besi ortamına eklenen bitki büyüme düzenleyicilerden BAP (1.0, 1.5 ve 2.0 mg l^{-1}), GA_3 (0.5, 1.0 ve 1.5 mg l^{-1}), 2-IP (0.75, 1.00 ve 1.25 mg l^{-1}), Kinetin (1.0, 2.0 ve 3.0 mg l^{-1}) ve TDZ (0.75, 1.00 ve 1.25 mg l^{-1}) test edilmiştir. Çalışmada eksplant sayısı, enfekte eksplant sayısı, sağlıklı eksplant sayısı, gelişmiş eksplant sayısı, sağlıklı eksplant oranı, gelişmiş eksplant oranı, nasırlı eksplant sayısı, kallus büyüme hızı, çoğalan eksplant sayısı, çoğalma hızı, çoğalma sayısı, köklenen eksplant sayısı, köklenme oranı ve kök sayısı incelenmiştir. Ancak daha çok sürgün oranları, sürgün sayıları ve kallus oluşumu üzerinde durulmuştur. En yüksek kardeşlenme oranları 2-IP (1.00, 0.75 ve 1.25 mg l^{-1}'de sırasıyla % 53.8, % 45.5 ve % 40.0) ve Kinetin (2.00 mg l^{-1}'de % 35.3)'de sağlanmıştır. En fazla kardeş sayısına 1.9 adet kardeş/eksplant ile 1.00 mg l^{-1} 2-IP dozunda ulaşılmıştır. Kinetin'nin 3.00 mg l^{-1} ve 2-IP'nin 1.25 mg l^{-1} dozları 1.8 sürgün ile başarılı sonuçlar alınan diğer uygulamalar olmuştur. Bu çalışma, sarımsağın yoğun üretiminde, dişlerin gövde disklerinden doğrudan bitkicik elde edilmesinde ve bunların üretime fide olarak dahil edilmesinde umut verici sonuçlara işaret etmektedir.

Anahtar kelimeler: Gövde disk kültürü, BAP, GA_3, 2-IP, Kinetin, TDZ, Sarımsak

1. Introduction

In recent years, climatic conditions, improper agricultural practices, and problems regarding production policy have caused various challenges in garlic production and the demand for garlic cannot be met (Turfan, 2022). The reproduction material problem is one of them.

The production of garlic includes one-stage cultivation where plants are obtained by planting the cloves directly into the field. Cloves separated from the heads are planted as seeds in autumn and spend the winter as small plants. These plants develop and form heads at the beginning of summer. The production cycle is completed when the head matures and the harvesting begins. When varieties with the weight of 1-1.5 g of cloves are preferred, 30-50 kg seed-cloves are needed per decare. If varieties with large cloves are desired to be used, 80-100 kg cloves per decare are required (Şalk et al., 2008). On the other hand, in the case of using medium-sized cloves in planting, 50-60 kg of cloves are used per decare in single-row planting, or 75-90 kg of cloves per decare in multi-row plantings (Günay, 2005). Garlic production is conducted by using the head or the cloves inside the heads, which is actually the consumed part of the garlic, as propagation material. Important economic losses are occurred for garlic producers due to the fact that growth from cloves is the preferred propagation method. These losses correspond approximately 10% of the garlics (80-100 kg cloves per decare) on the market.

Since garlic production cannot be conducted using true seeds, it relies completely upon asexual propagation. Using seedlings may be considered to solve the problem of propagation material in garlic production and also reduces the huge financial loss resulting from using cloves that are considered as consumption material. But the production of garlic using seedlings has not still reached a sufficient level. Accordingly, alternative methods should be employed to reduce these losses. *In vitro* techniques under laboratory conditions offer a conductive alternative to increase the production of garlic seedlings in a short time, and at a level to meet the demand without causing as much loss as in the case of using cloves as production material.

Globally, garlic plantlets are produced via *in vitro* tissue culture methods. However, the practical use of these plantlets, namely seedling production is still very limited (Haque et al., 1997; Xue et al., 1991; Garcia and Vargas, 2000). In the study by Haider et al. (2015), the highest percentage of plantlet regeneration was observed in the genotype G124 for the basal disc explants (63.33%) in MS medium supplemented with 2 mg l^{-1} NAA + 1 mg l^{-1} BAP. The survival rate of the plantlets after acclimatization varied from 40% in G123 to 70% in G121. Among the different phytohormone concentrations and combinations, MS basal medium without any growth regulators (M0) was found optimal for shoot-tip initiation (96% explants development) and plantlets elongation (56.26 mm) in garlic. For shoot proliferation, the M1 culture medium containing 1 mg l^{-1} BAP and 0.25 mg l^{-1} NAA provided the best results, giving a multiplication rate of 1.7 plantlets/explant. Shoots on M0 culture medium formed bulblets earlier. Multiple bulblets per explants were obtained from medium M22 containing 2 mg l^{-1} Kinetin and 0.1 mg l^{-1} NAA. Separated bulblets were transferred individually on bulbification media. Non-dividable bulblet was developed in various sizes.

Bulblet acclimatization step needs to be well studied for high quality cloves production. This efficient, optimized *in vitro* protocol were found to be successfull for large multiplication of virus-free garlic cultivars (Ayed et al., 2018).

This study has been attempted to determine the possibilities for the reproduction of garlic, which is a very important vegetable for production and consumption, by using tissue culture techniques intensively and in a short time. For this purpose, the proliferation and rooting status of garlic stem disc explants were investigated in *in-vitro* culture media, which were created by adding different growth regulators and different concentrations. It was aimed to develop rapid and mass seedling production possibilities for the garlic cultivation in Kahramanmaraş and its surroundings. Thus, preventing the increased economic and production losses. The study includes findings that may be beneficial in providing practical ways of obtaining seedlings for garlic producers in Türkiye and globally.

2. Materials and Methods

Local garlic (*Allium sativum* L.) plants grown extensively in Kahramanmaraş (Center and Pazarcık) were used as plant material; the cloves of the plants were the explant sources for this study.

The research was initiated with the disinfection of garlic cloves to be used as explants in order to prevent disease-induced contamination: the shells of the garlic cloves were peeled, washed three times with tap water, kept in 70% ethanol for 5 minutes, and in 5% sodium hypochlorite for 5 minutes, respectively. After the sterilization, the explants were washed 5-6 times with sterile distilled water; the water was removed by keeping them between drying papers for 3-5 minutes (modified from Gad El-Hak et al., 2011).

MS medium was used in the experiment (Murashige and Skoog, 1962). Study topics were plant growth regulators and different concentrations of these PGR's which were suggested by previous researchers (Haque et al., 1997; Myers and Simon, 1998; Myers and Simon, 1999; Fereol et al., 2002; Haque et al., 2003; Kyte et al., 2013) (*Table 1*).

MS nutrient medium was supplemented with plant growth regulators and adjusted to pH 5.7, and sterilized. Then tubes with a diameter of 2.5 cm and a length of 15 cm were filled with 10 ml of these nutrient media and placed in a sterile cabinet.

Table 1. Plant growth regulators used in the research

Plant Growth Regulator	Concentration (mg l^{-1})		
	Low	Middle	High
BAP	1.0	1.5	2.0
GA_3	0.5	1.0	1.5
2-IP	0.75	1.00	1.25
Kinetin	1.0	2.0	3.0
TDZ	0.75	1.0	1.25

Basal discs of garlic cloves were used to achieve the proliferation in the experiment. The discs were removed in a sterile cabinet via sterilized forceps and scalpel, and were planted in tubes containing MS nutrient media with different growth regulators and concentrations added as experiment subjects (*Figure 1*).

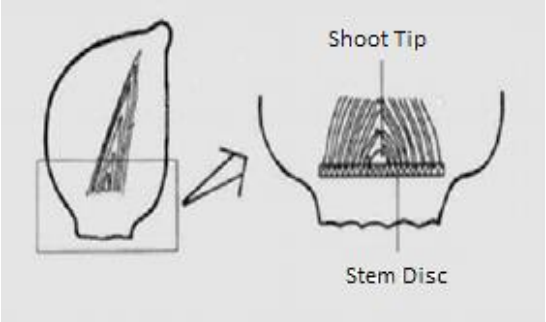

Figure 1. Plant parts were used as explants and cultured in tubes (modified from Ayabe and Sumi, 1998)

The explants were cultured in a climatic chamber at 22±2°C and 3000 lux light for 16 hours of light and 8 hours of darkness (Martin-Urdiroz et al., 2004). The experiments were continued for 45-60 days after planting the explants in the nutrient medium. When the experiment was concluded, observations and measurements were made on the basis of each application, and the data were evaluated according to the following criteria.

- Number of explants: total, infected, healthy, developed
- Healthy and developed explant rates
- Number of callused explants, callus growth rate
- Number of proliferated explants, proliferation rate, number of proliferation
- Number of rooted explants, rooting rate, number of roots

Each tube contained an explant and 48 tubes for BAP, and 36 tubes for GA_3, 2-IP, Kinetin, and TDZ were evaluated for each application. Statistical analyses were not applied in the experiments due to infection-related deaths and disruptions in plant growth.

3. Results and Discussion

This study aimed to reach a large number of materials with high regeneration potential, in other words, with rapid multiplication from explants. Accordingly, many criteria have been evaluated in the study. But proliferation rate, number of proliferations per explant, and callus formation potential were emphasized to interpretation of the results in terms of rapid and mass seedling production possibilities for the garlic cultivation.

3.1. BAP

Table 2 shows growth performances of 48 explants taken from basal discs of garlic cloves in MS nutrient media supplemented with three doses of BAP.

Table 2. The effect of BAP on explant development, callus development, proliferation, and rooting in garlic cultured in vitro

Doses (mg l^{-1})	Explants (number)	Infected explants (number)	Healthy explants (number)	Developed explants (number)	Healthy explant rate (%)	Developed explant rate (%)
1.0	48	12.0	36.0	28.0	75.0	58.3
1.5	48	10.0	38.0	31.0	79.2	64.6
2.0	48	16.0	32.0	29.0	66.7	60.4

Doses (mg l^{-1})	Callused explants (number)	Callus growth rate (%)	Proliferated explants (number)	Proliferation rate (%)	Proliferation (number)
1.0	7.0	25.0	5.0	17.9	1.6
1.5	9.0	29.0	6.0	19.4	1.8
2.0	8.0	27.6	7.0	24.1	1.6

Doses (mg l^{-1})	Rooted explants (number)	Rooting rate (%)	Roots (number)
1.0	10.0	35.7	2.1
1.5	11.0	35.5	2.0
2.0	16.0	55.2	2.4

Although identification techniques were not performed, there were infections we suspect caused by different harmful microorganisms in this study as in many cases in tissue cultures.

Concerning the number of healthy explants that were obtained by subtracting the number of infected explants from the total number of explants, 1.5 mg l^{-1} dose with 38.0 explants provided more explants than the other two doses. And it was possible to continue on the path with sufficient healthy explants at doses 1.0 mg l^{-1} (with 36.0 explants) and 2.0 mg l^{-1} (with 32.0 explants) of BAP. This is also supported by the healthy explant ratio data, which is calculated as the percentage rate of the number of healthy explants to the total explants. The highest developed explants were determined with 31 at 1.5 mg l^{-1}; followed by the doses 2.0 mg l^{-1} with 29.0 explants and 1.0 mg l^{-1} with 28.0 explants. This result was also emphasized by the ratio, which describes how much the growing explants are compared to the total explants in the study.

Although BAP did not offer a significant difference in the callus formation capabilities of explants, the highest values were reached with 9 callused explants and 29.0% callus growth rate (CGR) at the 1.5 mg l^{-1} dose. This application was followed by 2.0 mg l^{-1} (with 8 explants and 27.6% CGR) and 1.0 mg l^{-1} (with 7 explants and 25.0% CGR) doses. Among the BAP doses, the highest number of proliferated explants and the proliferation rates were in 2.0 mg l^{-1} with 7.0 and 24.1%, respectively. The dose was followed by 1.5 mg l^{-1} BAP dose (with 6.0 and a rate of 19.4%); the dose of 1.0 mg l^{-1} took the last place (with 5.0 and 17.9%). In terms of the proliferation number per explant, the most successful application was 1.5 mg l^{-1} with 1.8 while the amounts in 1.0 mg l^{-1} and 2.0 mg l^{-1} doses were 1.6.

It is understood that the enhancement in BAP caused an increase in number of rooted explants and in the rooting rate values. Hence, the highest number of rooted explants and the rooting rate were achieved on 2.0 mg l^{-1} with 16.0 and 55.2%, respectively. Number of roots and rooting rate values were recorded, respectively, as 11.0 roots and 35.5% in 1.5 mg l^{-1} and 10.0 roots and 35.7% in 1.0 mg l^{-1}. As with the number of rooted explants and the

rooting rate, the highest number of roots per explant was found at 2.0 mg l^{-1} (2.4 roots), followed by 1.0 mg l^{-1} (2.1 roots) and 1.5 mg l^{-1} (2.0 roots).

When the effects of BAP are evaluated on the proliferation rate and the proliferation number per explant, data showed that the doses of 1.5 and 2.0 mg l^{-1} provided better results. However, they gave a similar number of proliferation, 2.0 mg l^{-1} dose was slightly better in terms of proliferation rate. Haque et al. (2003) cultivated Bangladesh local garlic in MS nutrient medium containing combinations of different growth regulators and successfully obtained shoots in medium containing 2.0 mg l^{-1} BAP and 0.2 mg l^{-1} NAA. On the other hand, in a study by Ayabe and Sumi (1998) in which they cultured the stem discs of garlic cloves *in vitro* to obtain virus-free plants, they successfully used LS (Linsmaier and Skoog) medium supplemented with 0.1 mg l^{-1} NAA and 0.1 mg l^{-1} BA for reproduction. The differences in results between this study and study by Ayabe and Sumi (1998) at this point may be attributed to nutrient medium used and/or combined effect of NAA and nutrient medium.

Although the callus formation rate did not differ significantly between BAP doses, it can be stated that the best callus formation was achieved with a dose of 1.5 mg l^{-1}. A dose of 2.0 mg l^{-1} of BAP was also notable. Consistent with our results Myers and Simon (1998; 1999) found that the application of 2.66 mg l^{-1} BA provided the highest shoot formation rate.

When all the data obtained from BAP evaluated together, it can be stated that even though the use of BAP alone provided higher values in studied parameters, better results might be achieved from the combined use of some other cytokinins and auxins, as noted by Myers and Simon (1999) and Ayabe and Sumi (1998). It would be more appropriate to use auxins during the explant rooting phase of the study.

3.2. Gibberellic acid

Table 3 shows the effects of gibberellic acid on explant development, callus development, proliferation, and rooting in garlic.

Table 3. The effect of gibberellic acid on explant development, callus development, proliferation, and rooting in garlic cultured in vitro

Doses (mg l^{-1})	Explants (number)	Infected explants (number)	Healthy explants (number)	Developed explants (number)	Healthy explant rate (%)	Developed explant Rate (%)
0.5	36	9.0	27.0	21.0	75.0	58.3
1.0	36	7.0	29.0	22.0	80.6	61.1
1.5	36	10.0	26.0	18.0	72.2	50.0

Doses (mg l^{-1})	Callused explants (number)	Callus growth rate (%)	Proliferated explants (number)	Proliferation rate (%)	Proliferation (number)
0.5	3.0	14.3	4.0	19.0	1.5
1.0	4.0	18.2	5.0	22.7	1.6
1.5	6.0	33.3	3.0	16.7	1.7

Doses (mg l^{-1})	Rooted explants (number)	Rooting rate (%)	Roots (number)
0.5	8.0	38.1	1.4
1.0	9.0	40.9	1.9
1.5	7.0	38.9	1.7

Table 3 shows that the experiment started with 36 explants but concluded with 27.0 explants at 0.5 mg l^{-1}; with 29.0 explants at 1.0 mg l^{-1}; and with 26.0 explants at 1.5 mg l^{-1} doses of GA_3

GA_3 showed the most significant effect on callus formation in garlic at a dose of 1.5 mg l^{-1}. In this application, the numbers of callus forming explants were 6.0 and the callus growth rate was 33.3%. These properties were recorded as 4.0 and 3.0 callused explants, and 18.2% and 14.3% callus growth ratios at 1.0 and 0.5 mg l^{-1} doses, respectively. In terms of the number of explants and proliferation rate, the most successful GA_3 application was 1.0 mg l^{-1} as 5.0 explants were proliferated and the rate reached to 22.7%. At 0.5 and 1.5 mg l^{-1} doses of GA_3, 4.0

and 3.0 proliferated explants, and 19.0% and 16.7% of proliferation rates realized, respectively. The data obtained in the number of proliferations per explant varied depending on the doses. While the most successful application was 1.5 mg l^{-1} GA_3 dose (with 1.7 proliferation), 1.0 mg l^{-1} (with 1.6 proliferation) and 0.5 mg l^{-1} (with 1.5 proliferation) GA_3 doses formed the following ranks.

The effect of GA_3 on the number of rooted explants was less pronounced. The highest number of rooted explants was observed at 1.0 mg l^{-1} dose with 9.0 explants; this was followed by 0.5 mg l^{-1} with 8.0 explants and 1.0 mg l^{-1} with 7.0 explants. Rooting rate and number of roots in three GA_3 doses were listed as 1.0 mg l^{-1} (40.9% and 1.9 roots), 1.5 mg l^{-1} (38.9% and 1.7 roots), and 0.5 mg l^{-1} (38.1% and 1.4 roots).

Evaluating the effectiveness of GA_3 on callus formation revealed that 1.5 mg l^{-1} GA_3 application resulted in superior data in comparison to the other dosages. It was demonsrated that GA_3 showed the highest proliferation rate and proliferated explant by the dosages of 1.0 mg l^{-1} and 0.5 mg l^{-1}, whereas 1.5 mg l^{-1} dosage was found to be more effective at increasing proliferation per explant.

Similar results were obtained in the single-use of GA_3 in the MS environment by previous reports. Nasim et al. (2010) observed that, among the many hormone concentrations being studied, the highest rate of somatic embryo formation occurred in MS medium with 0.5 mg l^{-1} GA_3 supplement. Bekheet (2006), who use different doses of GA_3 + BA and BA + NAA combinations to shoot stimulation in garlic under *in vitro* conditions, emphasized that the GA_3 together with other growth regulators added to the MS environments were more effective in the promotion of the mentioned characteristics.

Although GA_3 had positive effects on proliferation and callus formation, it may be speculated that more favorable results can be obtained from the combining use of GA_3 and other growth regulators under *in vitro* conditions for the mass production of garlic.

3.3. 2-IP

The findings related to explant-callus development, and proliferation and rooting are presented in the *Table 4*.

Table 4. The effect of 2-IP on explant development, callus development, proliferation, and rooting in garlic cultured in vitro

Doses (mg l^{-1})	Explants (number)	Infected explants (number)	Healthy explants (number)	Developed explants (number)	Healthy explant rate (%)	Developed explant rate (%)
0.75	36	20.0	16.0	11.0	44.4	30.6
1.00	36	17.0	19.0	13.0	52.8	36.1
1.25	36	24.0	12.0	10.0	33.3	27.8

Doses (mg l^{-1})	Callused explants (number)	Callus growth rate (%)	Proliferated explants (number)	Proliferation rate (%)	Proliferation (number)
0.75	3.0	27.3	5.0	45.5	1.6
1.00	2.0	15.4	7.0	53.8	1.9
1.25	2.0	20.0	4.0	40.0	1.8

Doses (mg l^{-1})	Rooted explants (number)	Rooting rate (%)	Roots (number)
0.75	4.0	36.4	1.3
1.00	5.0	38.5	1.8
1.25	7.0	70.0	1.6

Table 4 indicates that our results did not presented any significant improvement regarding the effect of 2-IP on developed explant numbers. However, in reference to the dosage, the highest number of explants, 19.0, was found in 1.00 mg l^{-1} 2-IP treatment.

According to the number of callus forming explants and the callus formation data, 0.75 mg l^{-1} dosage resulted in higher amounts for those properties with 3.0 callused explants and 27.3% callus formation rate. The group ranking second consited of, in descending order, dosages of 1.25 mg l^{-1} and 1.00 mg l^{-1}, with the number of callus

forming explants of 2.0 and 2.0, respectively, and with callus formation rate of 20.0% and 15.4%, respectively. For the proliferated explants, the highest number, 7.0, was found in 1.00 mg l^{-1} 2-IP application, followed by 5.0 proliferated explants with 0.75 mg l^{-1} and 4.0 proliferated explants with 1.25 mg l^{-1} dosages, respectively. Proliferation performances of explants was found to be similar to proliferation rates. It was determined that 1.00 mg l^{-1} dosage produced best results with 53.8% proliferation rates, followed by dosages of 0.75 mg l^{-1} and 1.25 mg l^{-1} with the proliferation rates of 45.5% and 40.0%, respectively. The highest number of proliferation was 1.9 at 1.00 mg l^{-1} dose, while 1.25 mg l^{-1} with 1.8 and 0.75 mg l^{-1} with 1.6 were placed in the following rows.

With regards to the 2-IP application to the explants in the experiment, it was observed that the maximum root formation, that is, 7.0 rooted explants and highest rooting rate, that is, 70.0%, were obtained from the 1.25 mg l^{-1} dosage. As second and third ranking dosages, 1.00 mg l^{-1} and 0.75 mg l^{-1} produced 5.0 explants and 38.5% rooting, and 4.0 explants and 36.4% rooting, respectively. Regarding the number of roots per explant, the application with the best results was 1.00 mg/l with 1.8 roots, whereas the dosage of 1.25 mg l^{-1} with 1.6 roots and the dosage of 0.75 mg l^{-1} with 1.3 roots formed the following rows.

An overall evaluation of the impact of 2-IP in callus growth rate revealed that the highest callus formation rate was achieved at the dosage of 0.75 mg l^{-1} by 27.3%. In terms of proliferation rates and the number of proliferations per explant, it was observed that the best results were obtained from 1.0 mg l^{-1} dosage.

Garcia and Vargas (2000), who tested different combinations of 2-IP, BA, and Kinetin as well as NAA and IAA in MS medium in their study to obtain cloves from shoot tip culture of garlic (*A. sativum*) obtained the best results for proliferation from the combination of 0.5 mg l^{-1} 2-IP and 0.2 mg l^{-1} NAA. They determined that the highest proliferation rates were achieved by the combination of 2-IP + NAA. However, reports form Mohamed-Yasseen et al. (1994) were in line with our work, pointing out that 2-IP was able to produce more shoots when used alone.

Despite the promising results of this study on practical usability of garlic clove discs for rapid and mass production of planting material in garlic cultivation, when the results presented here is discussed with the earlier studies, it may have postulated that the promoting effects of PGRs are better expressed when different combinations of PGRs are tested at appropriate doses than the use of 2-IP alone to achieve this goal.

3.4. Kinetin

The effects of Kinetin dosages on explant development, callus development, proliferation, and rooting were summarized in *Table 5*.

Table 5. The effect of kinetin on explant development, callus development, proliferation, and rooting in garlic cultured in vitro

Doses (mg l^{-1})	Explants (number)	Infected explants (number)	Healthy explants (number)	Developed explants (number)	Healthy explant rate (%)	Developed explant rate (%)
1.0	36	8.0	28.0	20.0	77.8	55.6
2.0	36	6.0	30.0	17.0	83.3	47.2
3.0	36	11.0	25.0	15.0	69.4	41.7

Doses (mg l^{-1})	Callused explants (number)	Callus growth rate (%)	Proliferated explants (number)	Proliferation rate (%)	Proliferation (number)
1.0	5.0	25.0	5.0	25.0	1.4
2.0	3.0	17.6	6.0	35.3	1.7
3.0	2.0	13.3	4.0	26.7	1.8

Doses (mg l^{-1})	Rooted explants (number)	Rooting rate (%)	Roots (number)
1.0	8.0	40.0	2.1
2.0	9.0	52.9	2.4
3.0	7.0	46.7	2.6

Table 5 indicates the best growth, regarding the distribution of percent healthy explants to the developed explants, was at the dose of 1.0 mg l^{-1} Kinetin with 20.0 developed explants.

The most promising Kinetin dose for the number of explants forming callus and the rate of callus formation was 1.0 mg l^{-1} (5.0 explants and 25.0%, respectively). This was followed by 2.0 mg l^{-1} (3.0 explants and 17.6%, respectively) and 3.0 mg l^{-1} (2.0 explants and 13.3%, respectively) dosages.

The highest proliferation performance was found at the dosage of 2.0 mg l^{-1} with 6.0 explants and 35.3% proliferation rate. This was followed by 1.0 mg l^{-1} dosage with 5.0 number of explants and 25% proliferation rate, and 3.0 mg l^{-1} dosage produced the lowest number of explant (4.0) and proliferation rate (26.7%). Alternatively, however, 3.0 mg l^{-1} dosage resulted in higher proliferation figures (1.8) over those of the 2.0 mg l^{-1} (1.7) and 1.0 mg l^{-1} (1.4) Kinetin dosages.

The highest rooting values in garlic explants were obtained from the 2.0 mg l^{-1} of Kinetin with the 9.0 rooted explants and 52.9% rooting rate. Interestingly, though 1.0 mg l^{-1} of Kinetin application resulted in superior data on number of rooted explant in comparison to the 3.0 mg l^{-1} of Kinetin, it resulted in the lowest rooting rate (40.0%) and root number (2.1), indicating the beneficial effect of increasing Kinetin dosages up to 2.0 mg l^{-1} in rooting paramaters.

Data revealed that the best results in callus formation rate (25%) and callused explant number (5.0) were from the 1.0 mg l^{-1} dosage. The highest proliferation rate (25%) and the number of proliferation per explant (6.0) was recorded in the dose of 2.0 mg l^{-1}, whereas the number of proliferation per explant were highest with 3.0 mg l^{-1}. It may be speculated that the proliferation rates and proliferation numbers varied according to level of growth after proliferation formation was achieved. The findings obtained a study with grape and discussions of these findings with the results of the previous literature has supported that callus regeneration ratio and quality depend on the explant material and media. MS medium including BAP (1 mg L-1) + 2,4-D (0.1 mg L-1) was recommended for callus regeneration in node explants of Sultana grape (Pehlivan et al., 2017)

In a study conducted on proliferation in onion and garlic, Mukhopadhyay et al. (2005) reported that the combined use of 0.93 mg l^{-1} Kinetin and 1.07 mg l^{-1} NAA resulted in more successful results than other Kinetin and NAA combinations. These reports further confirmed the significant Kinetin effect at developing more shoots and roots in both onion and garlic.

In our study Kinetin conferred the highest positive effects on proliferation and callus formation, which are important components of mass production of garlic. However, it was understood, in the light of the literature on the subject that Kinetin should be used together with other growth regulators to maximize growth, and the application of auxin + cytokinin combinations can be more beneficial in proliferation and callus formation.

3.5. TDZ

Effects of TDZ application *in-vitro* culture of garlic are presented in *Table 6*.

Table 6 shows that the highest number of healthy explants with 29 was recorded in 0.75 mg l^{-1} TDZ, while it was least in 1.00 mg l^{-1} with 25.0. 0.75 mg l^{-1}. TDZ also produced the highest developed explant rate (52.8%) and number of developed explant (19.00), followed by the dosages of 1.00 mg l^{-1} and 1.25 mg l^{-1} with the number of developed explant of 15.0 and 13.0 and with the developed explant rate of 41.7%, and - 36.1%, respectively.

TDZ with 1.25 mg l^{-1} of dosage provided the highest number of callused explant (6.00) and the highest callus growth rate (46.2%), but it failed to produce proliferation. Number of proliferated explants and proliferation rate seemed to decrease with the increasing TDZ dosages. It appears that TDZ did not confer any advantage over the numbers of proliferated explants and proliferation rates.

Considering the effects of TDZ dosages on the rooting performances of garlic explants, 1.00 mg l^{-1} dosage produced the highest number of rooted explants (9.0) and rooting rate (60.0%). This dose was followed by 1.25 mg l^{-1} with the values of 7.0 and 53.8%, respectively. The lowest rooting rate, that is, 31.6% and lowest rooted explant number, that is 6.6, were obtained from the 0.75 mg l^{-1}. The maximum number of roots (2.7) was recorded in 1.25 mg l^{-1} and this was followed by 1.00 mg l^{-1} (2.6) and 0.75 mg l^{-1} (2.2) TDZ dosages.

In a study of Mohamed-Yasseen et al. (1994) on garlic, 2.2 and 7.5 shoots were obtained from whole and sliced cloves, respectively. However, these results realized when 0.1 µM NAA was added to the MS medium with 0.15 µmol TDZ. Alizadeh et al. (2013) have postulated that TDZ had a favorable effect on rooting when it was used alone on mesocotyl axes of garlic *Allium tuberosum* cloves. However, it failed to produce similar success in terms of proliferation and callus formation, pointing out that 1.0 mg l^{-1} dose of TDZ + 0.8 and 1.00 mg l^{-1} doses of 2.4 D should be used together for proliferation.

Table 6. The effect of TDZ on explant development, callus development, proliferation and rooting in garlic cultured in vitro

Doses (mg l^{-1})	Explants (number)	Infected explants (number)	Healthy explants (number)	Developed explants (number)	Healthy explant rate (%)	Developed explant rate (%)
0.75	36	7.0	29.0	19.0	80.6	52.8
1.00	36	11.0	25.0	15.0	69.4	41.7
1.25	36	9.0	27.0	13.0	75.0	36.1

Doses (mg l^{-1})	Callused explants (number)	Callus growth rate (%)	Proliferated explants (number)	Proliferation rate (%)	Proliferation (number)
0.75	4.0	21.1	2.0	10.5	1.0
1.00	2.0	13.3	1.0	6.7	1.0
1.25	6.0	46.2	0.0	0.0	0.0

Doses (mg l^{-1})	Rooted explants (number)	Rooting rate (%)	Roots (number)
0.75	6.0	31.6	2.2
1.00	9.0	60.0	2.6
1.25	7.0	53.8	2.7

These findings show that application of TDZ alone, which causes the least proliferation and callus formation among the plant growth regulators used in our study, can not deliver the desired results for regeneration and rapid reproduction in mass production.

4. Conclusions

From the viewpoint of the results presented here, it seems unlikely that the studied dosages of plant growth regulators would be sufficient to produce seedlings from stem disc of cloves for the mass production of garlic. This further confirmed earlier report on the effect of growth regulators on rate and number of proliferation in garlic and onion.

Nonetheless, our findings suggest that, with the manipulation of dosages beneficial effects of the studied plant growth regulators can translate into significant increases in proliferation and callus formation in stem disc of garlic cloves, and sufficient level of quantity and quality may be achieved to provide seedlings.

In conclusion, this study indicates promising results in *in vitro* shoot formation from stem discs of gloves, therefore, production of seedlings for mass production of garlic. However, further experiments with varying dosages and plant growth regulators, especially with cytokinin and auxin groups, in combinations, may be useful to fully judge on the effectiveness of generating plantlets directly from stem discs of the garlic cloves *in vitro*.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Sıcaklık Kontrollü Bir Mikrodalga Kurutucunun Geliştirilmesi ve Mantar Kurutma İşleminin Enerji ve Kalite Değerlerine Etkisi

Development of a Temperature Controlled Microwave Dryer and Effect of Mushroom Drying on Energy and Quality Values

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Öz

Mantar içerdiği %90 seviyelerindeki yüksek nemden dolayı hasat sonrası çabuk bozulabilen bir üründür. Meydana gelebilecek kimyasal, mikrobiyolojik ve enzimatik bozulmaları önlemek için ürün içerisindeki fazla nemin kurutularak uzaklaştırılması önemlidir. Kurutma işlemi üründeki fazla nemi ürünün kalite özelliklerini (fiziko-kimyasal, fitokimyasal vb.) kaybetmeden depo edilebilir bir nem değerine (%10-13) kadar düşürülmesi işlemidir. Bu çalışmada; geliştirilen sıcaklık kontrollü bir mikrodalga kurutucu kullanılarak 50±1,5°C, 60±2°C ve 70±2.5 °C sıcaklık değerlerinde kültür mantarı (şapkalı) kurutulmuştur. Kurutma işlemleri örneklerinin nem içeriği %92.85±0.29'den %10 nem seviyesine düşene kadar devam etmiştir. Çalışma kapsamında sıcaklık kontrollü mikrodalga yönteminin mantarın kuruma süresi, kuruma oranı, matematiksel modelleme, rehidrasyon kapasitesi, rehidrasyon oranı, renk, sertlik ve efektif difüzyon-aktivasyon enerji değerlerine olan etkisi araştırılmıştır. Bulgulara göre en kısa kuruma süresi 40 dakika ile 70 °C kurutma sıcaklığında belirlenirken en uzun kuruma süresi ise 210 dakika ile 50 °C kurutma sıcaklığında yapılan kurutma işlemlerinde belirlenmiştir. Taze mantarın renk değerlerini istatistiksel açıdan en iyi 50 ºC sıcaklıkta muhafaza ettiği tespit edilmiştir. En yüksek rehidrasyon kapasitesi 50 °C rehidre su banyosunda ve 70 °C sıcaklıkta kurutulan örneklerde belirlenmiştir. Sertlik özellikleri açısından incelendiğinde 70 °C sıcaklığın istatistiksel açıdan ($P<0.05$) daha uygun olduğu bulunmuştur. Rehidrasyon oranı ve kapasite değerleri açısından 60 °C sıcaklığın istatistiksel ($P<0.05$) olarak daha iyi olduğu tespit edilmiştir. Kurutulan mantarların efektif difüzyon değerleri $1.42\text{-}6.39x10^{-6}$ m^2 s^{-1} arasında değişmiştir. Kurutulan mantar örneklerinin aktivasyon enerji değeri ise 69.47 kJ mol^{-1} olarak hesaplanmıştır. İnce tabaka kuruma modelleri arasında kuruma verilerini en iyi Midilli-Küçük modeli (R^2: 0.9991) tahmin etmiştir. Bu şartlar altında elde edilen bulgulara göre kültür mantarının optimum veriler açısından 70 °C sıcaklıkta kurutulması önerilmektedir.

Anahtar Kelimeler: Mantar kurutma, Rehidrasyon sıcaklığı, Kurutma işlemi, Fiziko-kimyasal özellikler, Matematiksel modelleme, Efektif Difüzyon-aktivasyon enerjisi.

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Abstract

Mushroom is a perishable product from harvest due to the high humidity of 90%. When planning to occur, it is important to remove excess moisture from the microbiological evaluation of physical and enzymatic degradation. The drying process takes as long as a storable moisture treatment (10-13%) without losing the excess moisture in the product to determine the quality (physico-chemical, phytochemical, etc.). In this study; A temperature at the modeling temperature is 60±1.5 °C and 70±2.5 °C. Drying samples will continue from 92.85% to 10% humidity of the sample. Research that has drying rate, drying rate, rehydration capacity, rehydration rate, color, effect and effective di-activation energy values is used. According to the demonstration, the shortest drying time is estimated at 40 to °C, while the shortest drying time refers to long runs between 210 minutes and 50 °C. The color nominal collection of fresh mushroom is best preserved when stored at 50 ºC. The highest rehydration capacity is seen in the season passing from -70 °C in 50 °C rehydrated water. The hardness model is suitable for use at 70 °C ($P<0.05$). Rehydration rate and capacity properties were found to be better at 60 °C ($P<0.05$). Effective heights of dried mushrooms are 1.42-6.39x10^{-6} m^2 s^{-1} variety. The activation energy value of the dried mushroom sample was calculated as 69.47 kJ mol^{-1}. Among the thin layer drying models, the drying method was the best, I could choose the Pony-Little model (R2: 0.9991). The estimation for this case is that the cultivar is optimally targeted to mature at 70 °C.

Keywords: Mushroom drying, Rehydration temperature, Drying process, Physico-chemical properties, Mathematical modeling, Effective diffusion-activation energy

1. Giriş

Mantarlar, beslenme ve hastalık kontrolündeki önemli besin maddelerinden dolayı son yıllarda giderek artan popüler gıda ürünleri arasında yer almaktadır (Chang ve Miles, 1989; Tolera ve Abera, 2017). Protein, karbonhidrat, lif, mineral ve B vitamini açısından oldukça zengin olması başta kolesterol olmak üzere birçok sağlık sorunlarının ortaya çıkmasını engellemektedir. Dünya da mantar üretimi en çok yapılan ülke Çin'dir. Türkiye de ise mantar üretimi her yıl artış göstermektedir. Türkiye'de son beş yılda mantar üretimi yaklaşık 15.183 ton artış göstermiş ve 2020 yılında bu değer 55.455 ton mantar olarak kayıt edilmiştir (TÜİK, 2021). Üretim miktarı ve bünyesindeki yüksek su içeriğinden dolayı hasat sonrası muhafazası da oldukça önemlidir. Mevcut yüksek nem içeriği mantarda hızlıca mikrobiyal gelişmeyi artırmaktadır. Bu nedenle uygun bir muhafaza yönteminin belirlenmesi gerekmektedir.

Hasat sonra soğuk muhafaza koşulları olsa bile çeşitli morfolojik ve fizyolojik değişiklikler meydana gelebilmektedir. Ayrıca soğukta muhafaza yönteminde ilk yatırım ve enerji tüketim masraflarının yüksek olması ekonomikliğini zorlaştırmaktadır. Bu sebeple mantarın muhafaza işlemlerinde hem ürünün daha uzun süre depolanabilmesi hem de enerji tüketimi ve ilk yatırım masraflarının daha az olduğu yöntemleri seçmek önemlidir (Omari ve ark., 2018). Gelişmekte olan ülkeler arasında uygun muhafaza yöntemlerinin bilinmemesi ve/veya uygun alt yapının olmamasından kaynaklı hasat edilen taze ürünlerin yaklaşık %30-40 oranı çöpe gitmektedir. (Lewicki ve Lenart, 2006; Bonazzi ve Dumoulin, 2011). Muhafaza işlemleri arasında en yaygın olarak tercih edilen yöntem kurutmadır. Bu işlem biyolojik materyaldeki mevcut nemin belirli bir nem seviyesine kadar düşürülmesidir. Kurutma işlemlerinde birçok enerji kaynağı türü kullanılarak geliştirilen kurutucular mevcuttur. Bu amaçla literatürde yaklaşık 500 çeşit kurutucunun olduğu bildirilmesine rağmen bunlardan ortalama 100 tanesi yaygın bir şekilde kullanılmaktadır (Mujumdar, 2000; Şevik, 2013). Bu yöntemler arasında açıkta, mikrodalga, vakum, normal sıcak hava ve kızılötesi kurutma işlemleri ile bunların kombinasyonlarından oluşan hibrit kurutma tekniklerdir. Açıkta kurutma yöntemi pratiklik ve masraf açısından uygun bir yöntemdir. Fakat kurutulan tarımsal materyalin son kalite özellikleri ve üniform olmayan sıcaklık dağılımından dolayı kurutma işlemi uzun sürmektedir. Bununla birlikte açıkta kurutulduğundan dolayı biyolojik materyal çevresel etmenlerden olumsuz etkilenmektedir. Sıcak havayla kurutma işlemi ise mikrodalga yöntemine göre kuruma süresi daha uzun ve kalite özellikleri de daha düşük son ürünler elde edilmektedir. Mikrodalga kurutma işleminde elektromanyetik enerji direkt ürün içerisindeki su moleküllerini titreştirerek ısının daha üniform ve daha yüksek olmasını sağlamaktadır. Bu durum kurutma işleminin daha kısa sürmesine, kalite özelliklerinin daha yüksek olmasına ve enerji tüketiminin ise daha düşük olarak sonuçlanmasını sağlamaktadır (Omari ve ark., 2018). Fakat mikrodalga kurutma yönteminde güç parametresinin ürün üzerinde oluşturduğu sıcaklık değeri bilinmemektedir. Kurutma sıcaklığı ise ürünlerin kalite ve kuruma kinetiği üzerindeki en önemli etmenlerden biridir. Bu kapsamda yapılan çalışmada bir mikrodalga fırın üzerine temassız kızılötesi sıcaklık sensörü yerleştirilerek ürün yüzeyindeki sıcaklık değeri kontrol edilmiştir.

Literatürde mantar kurutma işlemiyle ilgili çeşitli çalışmalar bulunmaktadır. Mantar kurutulduğunda hemen hemen tüm lezzetini ve diğer özelliklerini koruyabilmektedir (Çelen ve ark., 2010). Das ve Arora (2018), mantar kurutma için mikrodalga destekli bir sıcak hava kurutucu geliştirmişlerdir. Çalışmada mantarın kuruma süresini 72 dakika olarak tespit etmişlerdir. Taşova ve Güzel (2020), 50, 60 ve 70 ºC sıcaklarda kültür mantarı kurutma işlemi yapmışlardır. En uzun kuruma süresini 50 ºC ile 9 saatte olduğunu bulmuşlardır. Hanmammadli (2020), 4 farklı mantar çeşidini (istiridye, kültür, kestane ve shiitake) 3 farklı mikrodalga gücünde (100, 200 ve 300 W) kurutmuştur. Çalışmada en kısa kuruma süresi 27 dakika ile kestane mantarında 300 W mikrodalgada belirlemiştir. Ancak daha önce yapılan mikrodalga kurutma çalışmalarında mantar yüzeyinde oluşan sıcaklığın kontrol edildiği bir kurutma çalışmasına rastlanılmamıştır.

Bu çalışmada geliştirilen sıcaklık kontrollü bir mikrodalga kurutucuda kültür mantarı kurutulmuştur. Farklı sıcaklık değerlerinin; kuruma süresi, kuruma oranı, modelleme, rehidrasyon, rehidrasyon oranı, rehidrasyon kapasitesi, renk, sertlik ve efektif difüzyon-aktivasyon enerji değerlerine etkisi araştırılmıştır.

2. Materyal ve Metot

2.1. Kurutma materyali

Çalışma materyali olarak mantar sebzesi kullanılmıştır. Ürün temini Tokat ilindeki bir marketten satın alınarak yapılmıştır. Nem tayini ve kurutma işlemleri için Tokat Gaziosmanpaşa Üniversitesi Biyosistem Mühendisliği

Bölümü kurutma laboratuvarına getirilmiştir. İşlemler bitinceye kadar ürünler +4±0.5 ºC sıcaklıkta muhafaza edilmiştir.

2.2. Nem tayini işlemi

Kurutma işlemi öncesinde taze mantarın yaş baza göre ilk nem içeriğinin belirlenmesi için ortalama 40±0.15 g örnek kullanılmıştır. Nem tayini işlemi sabit 70 ºC sıcaklıktaki bir etüvde ağırlık değişimi sabitlenene kadar kurutulmuştur (Yağcıoğlu, 1999). Yaş baza göre nem içeriği eşitlik (1) ve (2) kullanılarak hesaplanmıştır.

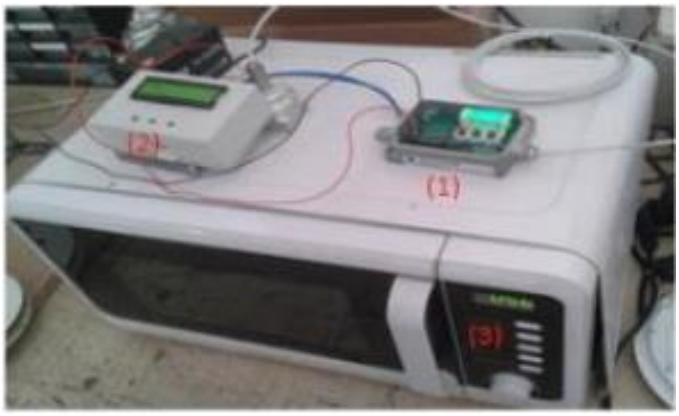
$$N_y = \frac{W_i - W_s}{W_i} \text{ x } 100 \qquad \text{(Eş.1)}$$

$$N_k = \frac{W_i - W_s}{W_s} \text{ x } 100 \qquad \text{(Eş.2)}$$

Burada; Ny: Yaş baza göre nem (%), Nk: Kuru baza göre nem (%), Wi: Yaş örneğin ağırlığı (g), Ws: Kuru örneğin ağırlığı (g).

2.3. Kurutma işlemi

Çalışmada ürünlerin kurutulması için geliştirilen sıcaklık kontrollü bir mikrodalga fırın kullanılmıştır (*Şekil 1*). Bu kurutucuda mikrodalga enerjileri fırın içerisine dağılarak kurutulan ürün tarafından absorbe edilip ayarlanan (istenilen) sıcaklık değerine kadar fırın çalıştır-kapa (kesikli) yöntemle çalışmaktadır. Mikrodalga kurutucuların düşük enerji tüketimi, kısa kuruma süresi ve yüksek kaliteli kuru ürün elde etme avantajlarından faydalanarak ürün yüzeyinde oluşan kurutma sıcaklığı da kontrol edilmektedir. Fırın içerisindeki cam tepsi üzerine yerleştirilen mantarın yüzey sıcaklığını ölçmek için mikrodalga üzerindeki temassız kızılötesi sıcaklık sensörü kullanılmıştır (*Şekil 1-1*). Ürün yüzeyinden ölçülen sıcaklık değeri önceden kontrol paneline önceden girilen kurutma sıcaklığına göre kontrol edilmiştir (*Şekil 1-2*). Kontrol paneli, ürünün yüzey sıcaklığı girilen kurutma sıcaklığına ulaştığında mikrodalga fırını otomatik olarak durdurmaktadır. Ürün sıcaklığı girilen kurutma sıcaklığının altına düştüğünde ise mikrodalga fırını otomatik olarak çalıştırmaktadır (*Şekil 1-3*). Çalışmada, mikrodalga fırının dinlenme süresi ise 15 saniye olarak belirlenmiştir (Polatcı ve Taşova, 2017).



Şekil 1. Sıcaklık kontrollü mikrodalga kurutucu

Figure 1. Temperature-controlled microwave dryer

2.4. Kurutma yöntemi

Kurutma işlemine başlamadan önce mantar yığınından temiz ve kararmamış örnekler seçilmiştir. Daha sonra mantarın sap kısımları ayrılmıştır. Kurutma işlemi için ortalama 35-40 g kadar ürün kullanılmıştır. Kurutma işlemleri geliştirilen sıcaklık kontrollü mikrodalga kurutucuda 50, 60 ve 70 ºC sıcaklıklarda paralel olarak yürütülmüştür. Kuruma işlemlerinde örneklerin son nem değeri yaş baza göre %10-14 seviyelerine kadar kurutulmuştur. Kurutulan örneklerin ağırlık değişimi ANDGF300 model hassas terazi (0.01 g) ile takip edilmiştir.

2.5. Renk ölçümü

Renk, gıdaların ve tarımsal ürünlerin en önemli kalite değerlerini ortaya koyan bir kriterdir. Ürünlerde meydana gelen enzimatik ve enzimatik olmayan reaksiyonlardan kaynaklı olumsuz renk değişimleri, market değerini önemli

seviyede etkilemektedir (Krokida ve ark., 2000; Adiletta ve ark., 2014; Polatcı ve ark., 2020). Taze ve kurutulmuş mantar örneklerinin L, a ve b değerleri Minolta marka CR300 model renk ölçer ile ölçülmüştür. Bu değerler kullanılarak kroma, hue, kahverengileşme indeksi ve toplam renk değişim değerleri hesaplanmıştır. "L" meyvenin parlaklık değerini ifade ederken 0-100 arasında değerler almaktadır. "a" kırmızı-yeşil ve "b" ise sarı-mavi renkleri temsil etmektedir. Bu değerler (+) işaretli olursa "a" kırmızıyı "b" sarı renkte olduğunu (–) işaretli değerler alırsa "a" yeşil ve "b" mavi renkte olduğunu göstermektedir (McGuire, 1992).

Kroma değeri, rengin doygunluğunu göstermektedir. Canlı renklerde yüksek değerler hesaplanırken solgun renklerde düşük değerler hesaplanmaktadır. Kroma değeri eşitlik (3) numaralı kullanılarak hesaplanmıştır.

Hue değeri, ölçülen kırmızılık ve sarılık değerleri kullanılarak hesaplanan bir renk radyantını ifade etmektedir. Hue değeri eşitlik (4) kullanılarak hesaplanmıştır.

$$C = (a^2 + b^2)^{1/2} \quad \text{(Eş.3)}$$

$$h^{\circ} = tan^{-1}\left(\frac{b^*}{a^*}\right) \quad \text{(Eş.4)}$$

Toplam renk değişim değeri (ΔE) taze mantarın renk değerlerini kurutma işlemleriyle ne kadar değiştiğini belirlemektir. Toplam renk değişim değerini eşitlik (5, 6, 7 ve 8) kullanılarak hesaplanmıştır (Çelen ve ark., 2015).

$$\Delta L = L_{taze} - L^2 \quad \text{(Eş.5)}$$

$$\Delta a = a_{taze} - a \quad \text{(Eş.6)}$$

$$\Delta b = b_{taze} - b \quad \text{(Eş.7)}$$

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad \text{(Eş.8)}$$

Kahverengileşme indeks değeri (BI) mantarın kurutma işlemi sonunda gerçekleşen kahverengilik değerini belirtmektedir. Kahverengileşme indeksi eşitlik (9) numaralı eşitlik kullanılarak hesaplanmıştır (Plou ve ark., 1999).

$$X = \frac{a+(1{,}75 \text{ x } L)}{[(5{,}645 \text{ x } L)+(a-(3{,}012 \text{ x } b))]} \quad \text{(Eş.9)}$$

$$BI = \frac{[100(x-0{,}31)]}{0{,}17} \quad \text{(Eş.10)}$$

2.6. Rehidrasyon değerleri

Kurutulan mantarların tekrar su alma miktarlarının yüksek olması istenir. Bu durum kuru ürünün kullanıldığı gıda ortamına aromasını ve tadını bırakması için arzu edilir. Kurutulan gıdaların rehidrasyon kinetiğinin araştırıldığı çalışmalarda rehidre için kullanılan suyun sıcaklığı da rehidrasyon parametrelerini (rehidrasyon hızı, oranı, kapasitesi) önemli seviyede etkilediği belirtilmektedir. Çalışma kapsamında farklı sıcaklarda kurutulan mantar örnekleri su banyosu cihazında (Şimşek Laborteknik marka-Türkiye SBD309 model) 50, 60 ve 70 ºC sıcaklıklarda bekletilmiştir. Rehidrasyon su sıcaklıklarının kurutulan mantarın rehisrasyon oranı ve kapasite parametrelerine etkisi araştırılmıştır. Kurutulan mantar örneklerinin rehidrasyon oranı (RO) eşitlik (11) kullanılarak hesaplanmıştır (Ertekin ve Yaldız, 2004). Kurutulan mantarların rehidrasyon kapasiteleri (RK) ise eşitlik (12) kullanılarak hesaplanmıştır (Chen ve ark., 2017).

$$RO = \frac{M_2}{M_1} \quad \text{(Eş.11)}$$

$$RK = \frac{(M_2 - M_1)}{M_1} \text{ x } 100 \quad \text{(Eş.12)}$$

Burada; M_2 herhangi bir t süresi anındaki nemli ürünün ağırlığını, M_1 ise kuru ürünün ilk ağırlığını temsil etmektedir. M_2 nemlendirilmiş ürünün ağırlığını, M_1 ise kuru ürünün ilk ağırlığını belirtmektedir.

2.7. Efektif difüzyon ve aktivasyon enerji değerlerinin belirlenmesi

Kurutma işlemlerinde ürünlerden nemin uzaklaşması Fick yasasının ikinci kanunu ile açıklanmaktadır. Bu kanun süreye bağlı olarak uzaklaşan nemin birim zamanda yayılan alan miktarını belirtmektedir. Efektif difüzyon değeri hesaplanırken ürün doku yapısının korunduğu ve nemin sadece difüzyon yolu ile ortamdan uzaklaştığı

varsayımı kabul edilmektedir. Bu değer eşitlik (14) kullanılarak hesaplanmıştır (Crank, 1979; Türker ve İşleroğlu, 2017).

$$MR = \frac{M-M_e}{M_0-M_e} = \frac{8}{\pi}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\ exp\left[(2n+1)^2\ \frac{\pi^2}{4}\frac{D_{ff}t}{L^2}\right] \quad \text{(Eş.13)}$$

$$In\ MR = In\frac{8}{\pi^2} - \frac{\pi^2 D_{eff}t}{4L^2} \quad \text{(Eş.14)}$$

Burada; Deff efektif difüzyon değerini ($m^2\ s^{-1}$), L ürünün dilim kalınlığının (m) yarısını ifade etmektedir. t ise ürünün kuruma süresini göstermektedir.

Aktivasyon enerjisi ürünün efektif difüzyon değerinin sıcaklığa bağlı değişimi Arrhenius eşitliğinde kullanılarak hesaplanmıştır (Karel ve Saguy, 1991). Bu fonksiyon eşitlik (15) te verilmiştir.

$$D_{eff} = D_0\ exp\left(-\frac{E_A}{RT}\right) \quad \text{(Eş.15)}$$

Burada; D_0 değeri difüzyon katsayısını ($m^2\ s^{-1}$), R değeri gaz sabitini (8.3143 kj $molK^{-1}$), Ea aktivasyon enerji değerini (kj mol^{-1}) ve T (Kelvin°) ise kurutma havası sıcaklığını ifade etmektedir.

2.8. Kuruma modeli

Kurutulan mantar örneklerinin süreye bağlı olarak ayrılan nem oranı değeri eşitlik (16) kullanılarak hesaplanmıştır.

$$ANO = \frac{M-M_e}{M_0-M_e} \quad \text{(Eş.16)}$$

ANO: Ayrılabilir nem oranı

M: Kurutulan materyalin anlık nem içeriği (g nem g $kurumadde^{-1}$)

Me: Kurutulan materyalin verilen durumdaki denge nemi (g nem g $kurumadde^{-1}$)

M_0: Kurutulan materyalin ilk nem içeriği (g nem g $kurumadde^{-1}$)

Kuruma eğrilerini oluşturmak için literatürde yaygın olarak kullanılan Lewis, Yağcıoğlu, Wang-Sing ve Midilli-Küçük ince tabakalı matematiksel modeller seçilmiştir. Modellere ait eşitlikler *Tablo 1*'de verilmiştir.

Tablo 1. Kurutma model eşitlikleri

Table 1. Drying model equations

Model ismi	Eşitlik	Kaynak	
Lewis	$ANO = \exp(-k.t)$	Lewis(1921)	(Eş.17)
Yağcıoğlu	$ANO = k.\exp(-h.t) + j$	Yağcıoğlu(1999)	(Eş.18)
Wang-Sing	$ANO = 1 + k.t + h.t^2$	Wang ve Singh (1978)	(Eş.19)
Midilli-Küçük	$ANO = h.\exp(-j.t^k) + (m.t)$	Midilli ve ark. (2002)	(Eş.20)

2.9. Kuruma hızı

Mantar örneklerinin kuruma hız değerlerine sıcaklıkların etkisi belirlenmiştir. Kuruma hız değerlerinin hesaplamak için eşitlik (21) kullanılmıştır.

$$KH = (M_t - M_{t+dt})/dt \quad \text{(Eş.21)}$$

Burada: M_t; t anındaki nem içeriği (g su g kuru $madde^{-1}$), dt; dakika, KH; kuruma hızı (g su g kuru $madde^{-1}$.dakika).

2.10. İstatistiksel analiz

Kurutulmuş örnekler ile taze örnekler arasındaki istatistiksel farkı ($P<0.05$) belirlemek için SPSS23 programında çoklu karşılaştırma testi (Duncan) yapılmıştır.

3. Araştırma Sonuçları ve Tartışma

3.1. Kuruma verileri

Mantar örnekleri, geliştirilen sıcaklık kontrollü bir mikrodalga kurutucu ile belirli bir nem seviyesine kadar kurutulmuştur. Mantar örneklerinin yaş baza göre ilk nem içeriği %92.85±0,29 olarak belirlenmiştir. Taşova ve Güzel (2020), çalışmalarında %92.90 nem içeriğine sahip mantar örneklerini etüvde 50, 60 ve 70 °C sıcaklıklarda kuruttukları ürünlerin kuruma süresini sırayla 9, 7.5 ve 4.5 saat olarak bulmuşlardır. Han, (2019) infrared kurutma tekniği ile kültür mantarının kurutulması üzerine yaptığı çalışmada taze mantarların ilk nem içeriğini %93 olarak bulmuştur. Bu çalışmada, literatürdeki kaynakla benzer sonuç elde edilmiştir. Tolera ve Abera (2017), çalışmalarında ozmotik ön işlem ve farklı kurutma yöntemlerinin mantarın besin kalitesi üzerine etkisini incelemişlerdir. Deneme materyali olan mantarın nem içeriğini %88.75±0.02 olarak bulmuşlardır. Bu farklılığın sebebinin mantar çeşidinin farklı olmasından kaynaklı olduğu düşünülmektedir. Kurutma işlemlerinde bu değer güvenli depolanabilir %10-14 nem seviyesine kadar düşürülmüştür. Çalışmada en uzun kuruma süresi 210 dakika ile 50 °C kurutma sıcaklığında tespit edilmiştir. En kısa kuruma süresi ise 40 dakika ile 70 °C kurutma sıcaklığında belirlenmiştir. Kurutma sıcaklığının 50 °C'den 70 °C'ye çıkarılması halinde kuruma süresinin %70.83 oranında azaldığı tespit edilmiştir. Şahin ve ark. (2012), 65 °C ve 75 °C kurutma sıcaklıklarında domates örneklerini kurutmuşlardır. Kurutma sıcaklığının artmasıyla kuruma süresinin ortalama %10 civarında azaldığını tespit etmişlerdir. Aktaş ve ark. (2013) kurutma sıcaklığının artması kurutulan meyvenin kuruma performansını (kuruma oranı, kuruma süresi vb.) olumlu etkilediğini tespit etmişlerdir.

3.2. Renk değerleri

Taze ve kurutulmuş mantar örneklerinin ölçülen ve hesaplanarak belirlenen renk değerleri *Tablo 2*'de verilmiştir.

Tablo 2. Mantar örneklerine ait ölçülen ve hesaplanan renk değerleri

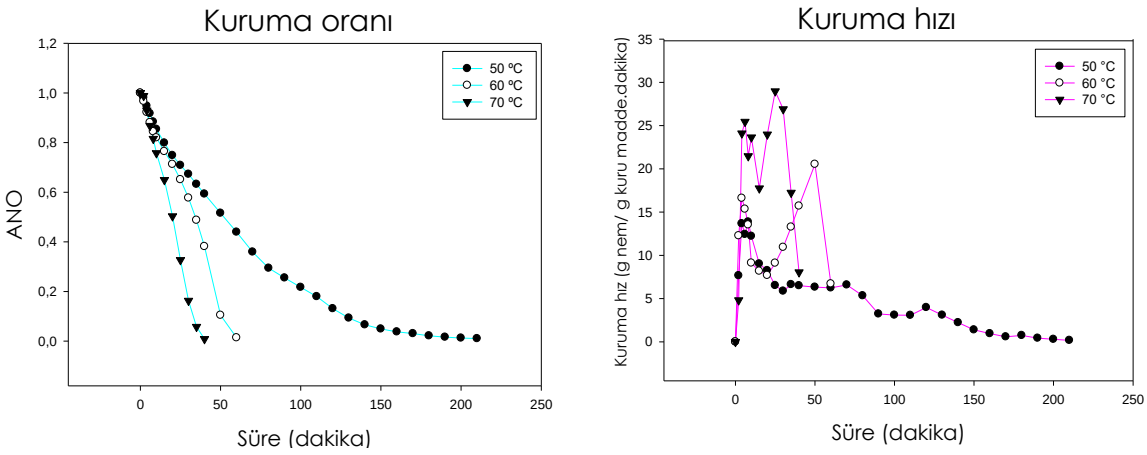
Table 2. Measured and calculated color values of mushroom samples

	L	a	b	C	Hue	ΔE	BI
Taze	88.08±3.13^{a}	3.23±0.29 ^{c}	9.71±1.96^{c}	10.25±1.91^{c}	71.13±2.90^{a}	-	-
50°C	43.71±2.09^{c}	10.79±0.94 ^{ab}	22.22±1.97^{b}	24.70±2.22^{b}	64.08±1.19^{d}	29.79±3.27^{c}	87.03±8.92^{a}
60°C	52.89±3.42^{b}	11.23±0.98^{a}	25.78±1.45^{a}	28.13±1.71^{a}	66.48±0.94^{c}	36.24±2.13^{b}	81.37±9.20^{b}
70°C	52.33±4.64^{b}	10.40±0.82^{b}	26.82±1.60^{a}	28.79±1.35^{a}	68.72±2.36^{b}	35.77±3.13^{b}	84.85±7.20^{ab}

Tablo 2'ye göre kurutulmuş örneklerin L, a ve b değerleri %5 önem seviyesinde taze örneklere göre istatistiksel açıdan bir fark bulunmuştur. L değerleri incelendiğinde 60 ve 70 ºC sıcaklıklarda ölçülen parlaklık değerleri arasında istatistiksel açıdan önemli düzeyde ($p<0,05$) bir fark olmamıştır. Kurutma sıcaklıklarının taze durumdaki mantara göre parlaklık değerlerini koruyamadığı tespit edilmiştir. Doğan ve ark. (2014), yaptıkları çalışmada istiridye mantarını farklı sıcaklıklarda ve belirli süre kurutmuşlardır. Kurutma işlemi sonucunda L değerleri 50, 60 ve 70 ºC sıcaklıklar için ortalama 70-75 arası değiştiğini belirtmişlerdir. Sarı/mavi renk değerleri incelendiğinde yine 60 ve 70 ºC sıcaklıklarda ölçülen b değerleri arasında istatistiksel açıdan önemli düzeyde ($P<0.05$) bir fark olmamıştır. Hanmammadli (2020), farklı mantar çeşitlerini kuruttuğu tez çalışmasında kültür mantarı örneklerinin b renk değerlerinin 13.80-22.25 arasında değiştiğini tespit etmiştir. Taze ürünün kroma (renk doygunluğu) değeri 10.25±1.91 olarak bulunmuştur. En düşük kroma değeri 50 ºC'de 24.70±2.22 bulunurken en yüksek değer ise 70 ºC ile 28.79±1.35 olarak belirlenmiştir. 60 ve 70 ºC sıcaklıklar için hesaplanan kroma değerleri arasında istatistiksel açıdan ($P<0.05$) bir fark yoktur. Kurutma sıcaklıklarının mantar örneklerinin kroma değerlerini artırdığı belirlenmiştir. Taze ürünlerin hue açısı 71.13±2.90 olarak hesaplanmıştır. Yapılan çalışmada en düşük hue açısı 50 ºC'de 64.08±1.19 olarak tespit edilirken en yüksek hue açısı ise 70 ºC sıcaklıkta 68.72±2.36 olarak bulunmuştur. Kurutma sıcaklıklarının mantar örneklerinin hue değerlerini artırdığı tespit edilmiştir. Kurutma sıcaklıklarının taze mantarın toplam renk değişimi üzerine etkisi istatistiksel açıdan önemli düzeyde olduğu bulunmuştur. En fazla renk değişimi 60 ºC sıcaklıkta 36.24±2.13 olarak belirlenirken en az ise 50 ºC sıcaklıkta 29.79±3.27 olarak belirlenmiştir. En düşük BI (kahverengileşme indeksi) değeri 60 ºC sıcaklıkta 81.37±9.20 olarak hesaplanırken en yüksek ise 87.03±8.92 hesaplanmıştır. Taze mantarın renk değerlerine istatistiksel açıdan en yakın 50 ºC sıcaklıkta kurutulan örneklerde tespit edilmiştir.

3.3. Kurutma parametrelerine ait değerler

Kurutulan mantar örneklerine ait mantarın kuruma hızı ve kuruma oranları Şekil 2' de verilmiştir.



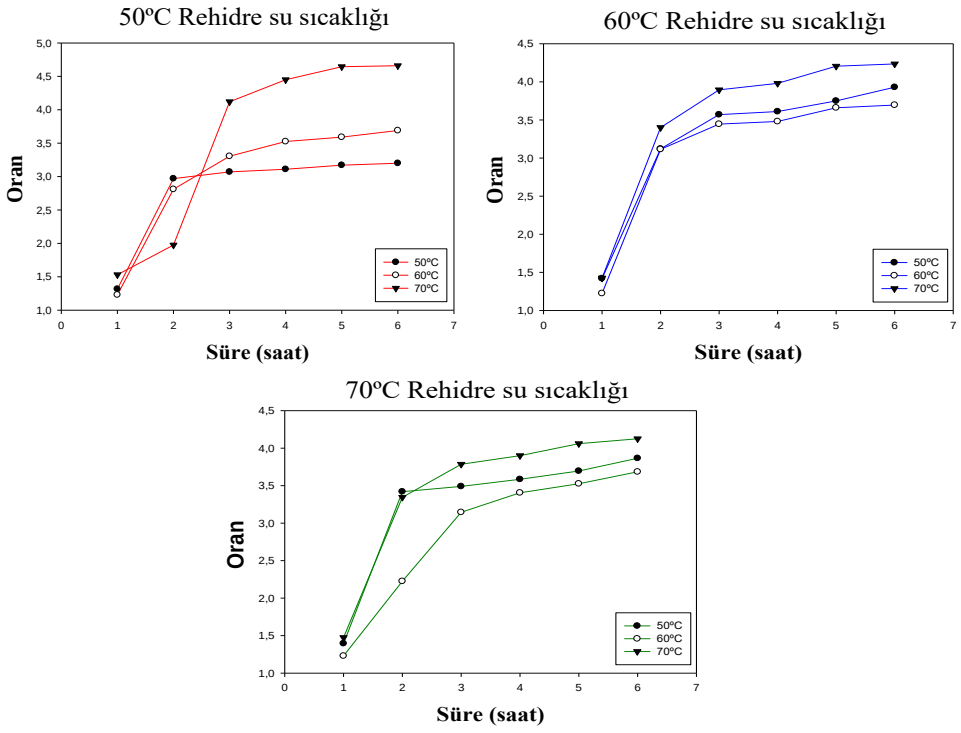
Şekil 2. Mantar örneklerine ait kuruma kinetiği ve kuruma hız eğrileri

Figure 2. Drying kinetics and drying rate curves of mushroom samples

Şekil 2'ye göre kurutma sıcaklıklarının kuruma hız değerlerine istatistiksel açıdan etkisinin önemli düzeyde olduğu görülmüştür. 50 °C' de yapılan kurutma işleminin kuruma hız değerleri 0.0028-0.2568 g nem.g kuru madde^{-1}.dakika arasında değiştiği tespit edilmiştir. 60 ve 70 °C' lerde ise bu değer sırasıyla 0.1097-0.3356 ve 0.0891-0.5031 g nem.g kuru madde^{-1}.dakika arasında değiştiği belirlenmiştir.

3.4. Rehidrasyon verileri

Kurutulan mantar örneklerine ait rehidrasyon ağırlık değişim değerleri *Şekil 3*'te verilmiştir.



Şekil 3. Farklı su banyosu sıcaklıklarındaki rehidrasyon eğrileri

Figure 3. Rehydration curves at different water bath temperatures

Çalışmada kurutma ve rehidre su sıcaklık değerlerinin mantar örneklerinin rehidrasyon ağırlık değişimlerine etkisinin önemli olduğu tespit edilmiştir. 50 °C rehidre su sıcaklığında kuru mantarların göstermiş olduğu rehidrasyon eğrileri incelendiğinde en yüksek rehidrasyon ağırlık değişimi 70 °C kurutma sıcaklığında belirlenmiştir. 60 ve 70 °C rehidre su sıcaklıklarında en yüksek rehidrasyon ağırlık değişimi yine 70 °C sıcaklıkta tespit edilmiştir. Tüm rehidrasyon ağırlık değişimleri birlikte değerlendirildiğinde en yüksek su alma miktarı 50 °C rehidre su sıcaklığında ve 70 °C sıcaklıkta kurutulan örneklerde belirlenmiştir. Taşova ve Güzel (2020), yaptıkları çalışmada kültür mantarını 50, 60 ve 70 ºC sıcaklıklarda 12.54±1.21 kuru baz (k.b.) değerinden 0.13±0.02 (k.b.) son nem değerine kadar kurutmuşlardır. Kurutma sonrasında mantarlara uygulanan farklı rehidre su sıcaklıklarının rehidrasyon oranına etkisine bakılmıştır. Deneme sonucunda en yüksek rehidrasyon oranı 1.84 ile 70 ºC sıcaklıkta yapılan su banyosunda ve 50 ºC sıcaklıkta kurutulan mantar örneklerinde tespit edilmiştir. Hanmammadli (2020), mikrodalga kurutma yöntemi ile çeşitli mantarlara kurutma işlemi uygulamıştır. Sonuçlar incelendiğinde 100, 200 ve 300 W mikrodalga uygulamalarıyla kurutulan kültür mantarı örneklerinin rehidrasyon oranı değerleri sırasıyla 1.55, 0.79 ve 1.01 olarak bulmuştur.

3.5. Rehidrasyon parametreleri ve sertlik değerleri

Kurutulan mantar örneklerine ait sertlik rehidrasyon oranı ve rehidrasyon kapasite değerleri *Tablo 3*'te verilmiştir.

Tablo 3. Mantar örneklerine ait sertlik, rehidrasyon oranı ve kapasitesi değerleri

Table 3. Hardness, rehydration rate and capacity values of mushroom samples

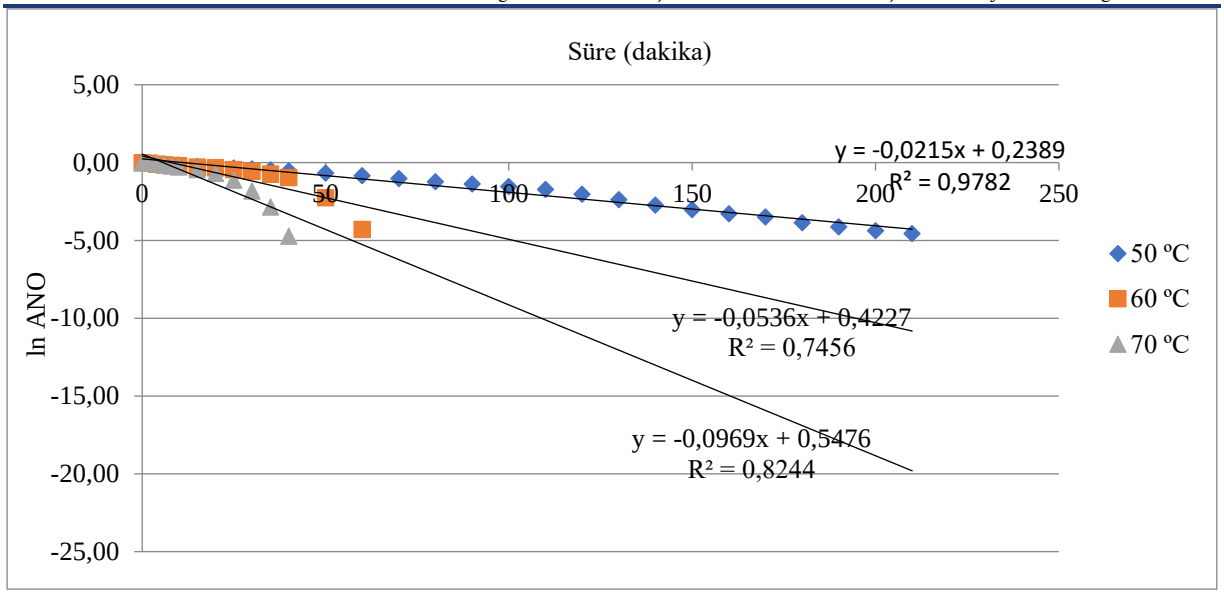
Kurutma sıcaklıkları	S	Rehidrasyon su sıcaklığı	RO	RK
Taze	51.83±3.97^{c}	-	-	-
50 ºC	66.30±1.95^{a}	50 ºC	2.45±0.09^{b}	59.10±1.49^{b}
		60 ºC	3.00±0.15^{a}	66.63±1.66^{a}
		70 ºC	3.05±0.09^{a}	67.13±0.97^{a}
60 ºC	66.80 ±2.89^{a}	50 ºC	2.78±0.06^{ab}	63.91±0.84^{ab}
		60 ºC	3.02±0.29^{a}	66.72±3.19^{a}
		70 ºC	2.95±0.35^{a}	65.88±4.08^{a}
70 ºC	61.80±2.04^{b}	50 ºC	2.77±0.05^{ab}	63.92±0.60^{ab}
		60 ºC	3.02±0.20^{a}	66.78±2.25^{a}
		70 ºC	2.80±0.23^{ab}	64.16±3.01^{ab}

^{ab}Farklı üst simgelere sahip bir satır içindeki değerler, P<0.05'te önemli ölçüde farklılık gösterir. S: Sertlik, RO: Rehidrasyon oranı, RK: Rehidrasyon kapasitesini göstermektedir.

Tablo 3'e göre kurutma sıcaklıklarının mantarın sertlik değerlerine etkisi istatistiksel açıdan (P<0.05) önemli düzeyde olduğu bulunmuştur. 50 ve 60 °C sıcaklıklarda kurutulan mantar örneklerinin sertlik değerleri taze ve diğer kurutma sıcaklığına göre istatistiksel açıdan daha yüksek olduğu belirlenmiştir. 50 °C rehidre su sıcaklığında istatistiksel açıdan (P<0.05) en yüksek rehidrasyon oranları ve kapasitesi 60 ve 70 °C'lerde kurutulan örneklerde tespit edilmiş. 60 °C rehidre su sıcaklığında istatistiksel açıdan (P<0.05) en yüksek rehidrasyon oranı ve kapasitesi yine 60 ve 70 °C'lerde kurutulan örneklerde belirlenmiştir. 70 °C rehidre su sıcaklığında istatistiksel açıdan en yüksek rehidrasyon oranı ve kapasitesi ise 60 °C'de kurutulan örnekte bulunmuştur. Kurutulan mantar örnekleri sertlik özellikleri açısından kıyaslandığında 70 ºC sıcaklıkta yapılan işlemin istatistiksel açıdan (P<0.05) daha uygun olduğu belirlenmiştir. Kurutulan mantar örnekleri rehidrasyon oranı ve kapasite özellikleri açısından değerlendirildiğinde 60 ºC sıcaklıkta yapılan işlemin istatistiksel açıdan (P<0.05) daha iyi olduğu bulunmuştur.

3.6. Efektif difüzyon ve aktivasyon enerji değerleri

Kurutulan mantar örneklerine ait süreye bağlı ln ANO değerleri *Şekil 4*'te verilmiştir.



Şekil 4. ln ANO değerler

Figure 4. ln ANO values

Kurutma sıcaklıklarının efektif difüzyon ve aktivasyon enerji parametrelerine etkisi *Tablo 4*'te verilmiştir.

Tablo 4. Efektif difüzyon ve aktivasyon enerji

Table 4. Effective diffusion and activation energy

Kurutma sıcaklıkları	Efektif difüzyon ($m^2 s^{-1}$)	Aktivasyon enerji (Kj mol^{-1})
50 ºC	$1.42x10^{-6}$	
60 ºC	$3.53x10^{-6}$	69.47
70 ºC	$6.39x10^{-6}$	

Tablo 4'e göre kurutma sıcaklıklarının efektif difüzyon değerlerini önemli düzeyde etkilemiştir. Kurutulan mantarların efektif difüzyon değerleri $1.42\text{-}6.39x10^{-6}$ m^2 s^{-1} arasında değişmiştir. Kurutma sıcaklıklarının artmasıyla efektif difüzyon değerleri artmıştır. Kurutulan mantar örneklerinin aktivasyon enerji değeri ise 69.47 kJ mol^{-1} olarak hesaplanmıştır. Doymaz ve Aktaş (2018), yaptıkları çalışmada sıcak hava kurutucusunda, 40, 50, 60 ve 70 °C sıcaklıklarda patlıcan kurutmuşlardır. Kurutma havası sıcaklığının artmasıyla birlikte kurutulmuş patlıcan dilimlerinin efektif difüzyon katsayısı değerlerinin arttığını belirtmişlerdir. Taşova ve Güzel (2020), üç farklı (50, 60 ve 70 °C) kurutma sıcaklığında kurutulan kuşburnu meyvesinin kurutma havası sıcaklığı ürünün efektif difüzyon değerini etkilediği ve sıcaklık değerinin artması ile efektif difüzyon değerinin arttığı ve en yüksek efektif difüzyon değerini ise 70 °C kurutma sıcaklığında belirlediklerini ifade etmişlerdir.

3.7. Modelleme Verileri

Kurutulan mantar örneklerine ait matematiksel modelleme değerleri *Tablo 5*'te verilmiştir.

Tablo 5'e göre Lewis modeli kuruma verilerini en iyi 50 ºC'de modellemiştir. Wang-Sing. Yağcıoğlu ve Midilli-Küçük modelleri kuruma verilerini yine en iyi 50 ºC'de modellemiştir. Tüm kurutma modeller arasında kuruma verilerini en iyi Midilli-Küçük modeli (R^2: 0.9991) tahmin etmiştir. Çalışmada kullanılan matematiksel modellerin tümü istatistiksel açıdan güvenli ($P<0.05$) olduğu bulunmuştur. Bu çalışmada mantar için en uygun kurutma modelinin belirlenmesi kurutma işleminin kontrolünün sağlanması açısından bir avantaj sağlayacağı düşünülmektedir.

Tablo 5. Modelleme eşitliklerine ait hesaplanan değerler

Table 5. Calculated values of modeling equations

Model Eşitlikleri	Sıcaklık (ºC)	R^2	p	k	h	j	m
Lewis	50 ºC	0.9959	<0.0001	0.0153	-	-	-
	60 ºC	0.9480	<0.0001	0.0241	-	-	-
	70 ºC	0.9533	<0.0001	0.0425	-	-	-
Wang Sing	50 ºC	0.9983	<0.0001	-0.0111	3.1453	-	-
	60 ºC	0.9937	<0.0001	-0.0138	-5.1387	-	-
	70 ºC	0.9956	<0.0001	-0.0248	-3.5182	-	-
Yağcıoğlu	50 ºC	0.9990	<0.0001	1.1007	0.0124	-0.1006	-
	60 ºC	0.9906	<0.0001	16.5601	0.0010	-15.5529	-
	70 ºC	0.9968	<0.0001	8.6395	0.0033	-7.6039	-
Midilli- Küçük	50 ºC	0.9991	<0.0001	1.1208	0.9802	0.0083	-0.0002
	60 ºC	0.9913	<0.0001	0.0006	1.0131	0.0079	-0.0162
	70 ºC	0.9982	<0.0001	1.5783	0.9947	0.0048	-0.0054

R^2: Kararlılık katsayısı, p: Önemlilik seviyesi, k-h-j-m: Model katsayıları

4. Sonuç

Mantarın kuruma özelliklerinin incelendiği bu çalışma kapsamında kurutma sıcaklıklarının artmasıyla kuruma sürelerinin önemli düzeyde azalttığı tespit edilmiştir. Renk değerleri açıdan en uygun 50 ºC sıcaklıkta yapılan kurutma işlemi olmuştur. Kurutulan mantar örnekleri arasında en yüksek geri su alma miktarı 50 °C rehidre su sıcaklığı ortamında ve 70 °C sıcaklıkta kurutulan örneklerde belirlenmiştir. Kurutulan mantar örneklerinin sertlik değerleri artmıştır. Sertlik özelliği açısından 70 °C sıcaklıkta kurutma işleminin yapılması daha uygun olduğu bulunmuştur. Kurutulan mantar örnekleri rehidrasyon oranı ve kapasitesi özellikleri açısından değerlendirildiğinde 60 °C sıcaklıkta yapılan işlemin optimum olduğu görülmüştür. Kurutma sıcaklıklarının artmasıyla efektif difüzyon değerleri arttığı ve mantarın aktivasyon enerji değeri ise 69.47 kJ mol^{-1} olarak hesaplanmıştır. Belirlenen matematiksel modeller arasında kuruma verilerini en iyi Midilli-Küçük modelinin (R^2: 0.9991) tahmin ettiği tespit edilmiştir.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Molecular Determination of the Presence of Some Grapevine Viruses and Phylogenetic analyses of Grapevine Virus A in Tokat Province Grapevine Area*

Tokat İli Asma Alanında Bazı Asma Virüslerinin Moleküler Olarak Belirlenmesi ve Grapevine Virus A'nın Filogenetik Analizi

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Abstract

Grapevine (*Vitis* spp.) is one of the major fruit crop with high socioeconomic importance for Turkey. In vineyards, many harmful organism, especially virus infections, weaken the plant and lead to decreases in yield and quality, so it takes the lead in quarantine and certification. This study was carried out to determine some viral agents that cause yield loss in vines produced in Tokat, where viticulture is very important. Samples were collected from young leaves and one-year-old shoots of grapevines showing virus symptoms from some vineyard areas in Tokat Center and its districts. Collected 189 grapevine samples were subjected to the RT-PCR test, which is a molecular method using virus-specific primers, to detect the presence of *Grapevine pinot gris virus* (GPGV), *Grapevine virus A* (GVA), *Strawberry latent ringspot virus* (SLRSV). Out of a total of 189 plant samples, 80 (42.32%) of GVA, 3 (1.58%) of GPGV were detected and SLRSV (0%) was not detected. More than one virus was found in 2 (1.05%) of 189 tested samples. It was determined that the most common virus was GVA, the least detected virus was GPGV in plant samples collected from Tokat Center and its districts. Bidirectional sequence analysis of RT-PCR products of GVA-infected isolates were performed and phylogenetic analyzes were done by comparing them with reference isolates after they were aligned with the MEGAX computer program. Based on phylogenetic analysis studies, GVA showed differential branching with isolates registered in GenBank and isolates obtained in the study. GVA-infected isolates showed similarity with reference isolates at rates of 92-94%. In this study, molecular analysis of Turkish GVA isolates was performed. This molecular information is important as it will shed light on future studies.

Keywords: Phylogenetic analysis, Grapevine virus A, Strawberry latent ringspot virus, Grapevine pinot gris virus, Tokat, *Vitis vinifera*, RT-PCR

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Öz

Türkiye bağcılığı sosyoekonomik anlamda en önemli ürün gruplarının biridir. Bağlarda birçok zararlı organizma grubu özellikle de virüs enfeksiyonları bitkiyi zayıflatıp, verim ve kalitesinde azalmalara yol açtığından karantina ve sertifikasyonda başı çekmektedir. Bu çalışma, bağcılığın çok önemli olduğu Tokat ilinde üretilen asmalarda verim kaybına neden olan bazı viral etmenleri tespit etmek amacıyla yapılmıştır. Tokat Merkez ve ilçelerindeki bazı bağ alanlarından virüs semptomu gösteren asmaların genç yapraklarından ve bir yaşındaki sürgünlerinden örnekler alınmıştır. Toplanan 189 asma örneğine Grapevine pinot gris virus (GPGV), Grapevine virus A (GVA) ve Strawberry latent ringspot virus (SLRSV) varlığını tespit etmek için virüse özgü primerler kullanılarak moleküler bir yöntem olan RT-PCR testine tabi tutulmuştur. Toplam 189 asma örneğinden 80 (%42.32) GVA, 3 (%1.58) GPGV enfeksiyonu tespit edilmiş ve hiçbir örnekte SLRSV (%0) tespit edilmemiştir. Test edilen 189 asma örneğinin 2'sinde (%1.05) birden fazla virüs tespit edilmiştir. Tokat Merkez ve ilçelerinden toplanan bitki örneklerinde en sık görülen virüsün GVA, en az tespit edilen virüsün ise GPGV olduğu belirlenmiştir. GVA ile enfekteli izolatların RT-PCR ürünlerin çift yönlü sekans analizi analizleri yapılmış ve MEGAX bilgisayar programı ile hizalandıktan sonra referans izolatlarla karşılaştırılarak filogenetik analizleri yapılmıştır. Filogenetik analiz çalışmalarına göre, GVA, GenBank'ta kayıtlı izolatlarla ve farklı çalışmada elde edilen izolatlarla farklı dallanma göstermiştir. GVA ile enfekte izolatlar referans izolatlarla %92-94 oranında benzerlik göstermiştir. Bu çalışmada Türk GVA izolatlarının moleküler analizi yapılmıştır. Bu moleküler bilgilerin ileride yapılacak çalışmalara ışık tutacağı öngörülmektedir.

Anahtar Kelimeler: Filogenetik analiz, Grapevine virus A, Strawberry latent ringspot virus, Grapevine pinot gris virus, Tokat, *Vitis vinifera*, RT-PCR

1. Introduction

Grape, which has great importance in human nutrition, is a type of fruit that is consumed both fresh and dry. Our country, is located on the most favorable belt of the world for viticulture; Due to its location in the center of the geography where the gene centers of the vine intersect and where it was first cultivated, it has a very old and deep-rooted viticulture culture and a rich vine gene potential (Durgut and Arın, 2005). It is also an important export product for Turkey's economy (Kaplan and Bayhan, 2017).

Tokat is a province that demonstrates the peculiarities of the transitional climate between the region of Central Anatolia and the Eastern Black Sea region. Viticulture is an important agricultural industry for Tokat and is widely practiced in the districts of Central, Zile, Erbaa, Pazar, Turhal, and Niksar. In Tokat province, 51,762 tons of products are produced from an area of 62,259 hectares (TUIK, 2019). Narince variety, which is grown in the Tokat region and forms a large part of the vineyards, has an important place in commercial ivy leaf production.

The most important factors that reduce the yield and quality of grapes in the vineyard areas are the diseases and harmful factors of the cultivated plant. Among them, virus diseases cause yield losses by affecting crop plants in varying degrees. Pinot gris grapevine virus (GPGV), one of the important viral diseases of vineyards, is a single-stranded RNA virus with positive sensitivity, belonging to the genus *Trichovirus*. It affects the growth of leaves and fruits of grape plants and is known for its resemblance to the internal necrosis virus of grapefruits. It is a new virus, which was first detected in Italy in 2012, and the next-generation sequence analysis method is widely used in the field of plant virology. The entire genome sequence of the Italian isolate GPGV was analyzed and reported to be very closely related to the internal Grapevine necrosis virus (GINV), which belongs to the genus *Trichovirus* (Giampetruzzi et al., 2012). This virus, which has been found mainly in wine grapes in Europe, has so far only been detected in the table grape variety Tamnara, which causes cluster necrosis symptoms in Korea, except in Europe (Cho et al., 2013). It is called by this name because it was first detected in the Pinot gris grape variety in Northern Italy. In the following years, this virus was detected in Korea (Cho et al., 2013), Slovenia (Plesko et al., 2014), Slovakia, Czech Republic (Glasa et al., 2014), France (Beuve et al., 2015), and Turkey (Gazel et al., 2016) and records from different countries are reported every year (Saldarelli et al., 2017). GPGV was detected and recorded in a reverse transcriptase-polymerase chain reaction (RT-PCR) tick assay using specific primers with grape mite samples known as *Colomerus vitis* (=Eriophyes) collected from GPGV-infected vines and symptomatic sites on the leaves. It has been reported to be a possible carrier of this virus (Malagnini et al. 2016).

Grapevine virus A (GVA) is a viral agent occurring worldwide in Vitis species, with filamentous particles 800 nm in length and features showing distinct cross-bands. The virus is a grapevine pathogen that is difficult to transmit to a very narrow range of herbaceous hosts by inoculation of plant sap, transporting infected material over medium and long distances, and between plants by vectors of the cochlea. It is also known for the symptoms seen on the woody part of the vine. Swelling occurs at the graft site, which is seen as rootstock and scion incompatibility. It causes noticeable stunting in vines (Akbaş et al., 2008). GVA has been detected in several countries in the Middle East, including Syria (Mslmanieh et al., 2006), Jordan (Osman and Rowhani, 2008; Osman et al., 2013), Egypt (Fattouh et al., 2014), Afghanistan (Digiaro et al., 1999), Lebanon (Haidar et al., 1996), Palestine (Alkowni et al., 1998; Alkowni et al., 2004), Turkey (Koklu et al., 1998, Balsak and Buzkan, 2021), and other countries such as Italy (Ioannou, 1993), Spain (Zabalgogeazcoa et al., 1997), USA (Goszczynski and Habili, 2012), and Portugal (Digiaro et al., 1999).

Strawberry latent ringspot virus (SLRSV) has a wide host range. It is found among rose, strawberry, peach, nectarine, mint, cucumber, sugar beet, lettuce, tomato, tobacco, vineyard, and many weed hosts (Murant, 1976). Within the geographical range of SLRSV, there are most European countries, Israel, Turkey, Canada, the USA, Australia, and New Zealand (Anonymous, 2020). SLRSV, a *nepovirus*, is transmitted in nature by the nematode *Xiphinema diversicaudatum* (Micol.). The nematode has been determined to carry the virus in both the larval and adult stages. The virus can also be transmitted mechanically, by graft, and by seeds (Lister, 1964; Murant, 1976; Lamberti et al., 1986). The virus is known to cause curling and narrowing of leaves, shrubs, decreased yield, and deformation of fruits and seeds.

Numerous studies have been carried out on grapevines in Turkey; Çığşar (2002) collected and tested a total of 1001 samples to determine the status of viruses and virus-like diseases in the important vineyard areas of the Southeastern Anatolia Region and Nevşehir province between 1999-2002. Biological and serological diagnostic

methods were used on the collected samples. The results showed that the most common virus in the region was GVA (41.2%), followed by Grapevine leafroll-associated virus-1 (GLRaV-1) (38.1%), GFLV (8.1%), and Grapevine fleck virus (GFkV) (5.4%).

In the study conducted by Değer (2015), samples were collected from 11 vineyards in Hatay and 2 vineyards in Gaziantep. According to ELISA results, most common viruses were GLRaV-1 (55.56%), GLRaV 4-9 (43.14%), GLRaV-2 (15.69%), GLRaV-3 (12.42%) and followed by GVA (4.57%) and GLRaV-6 (%0.65). None of the samples, were found infected with GLRaV- 5, GLRaV-7 and Grapevine virus B (GVB). Based on the RT-PCR results, tested samples were infected with GLRaV-1, GLRaV-6, GLRaV-3, GVA, GVB and Grapevine virus D (GVD) at rates 23.94%, 15.38%, 14.77%, 13.64%, %1.26, 1.20%, respectively.

In the vineyard samples collected from Tekirdağ province by Kocabağ et al. (2019), 43.62% GPGV and 1.04% Grapevine Syrah virus-1 (GSyV1) were detected. In the samples collected from Hatay province, only 0.9% GSyV1 was detected, and the tested samples were clear in terms of GPGV, GRBaV, and GRLDaV. In the RT-PCR analyzes of Tekirdağ samples for GPGV, when primers that amplify partial coat protein, movement, and replicase genes were used, PCR products of 411 bp, 302 bp, and 618 bp, respectively, were obtained. As a result of a direct bidirectional sequence analysis of these products, they reported that the nucleotide sequences of all three gene regions showed high homology with different GPGV isolates registered in the GenBank.

This study, it was aimed to define the presence of GVA and SLRSV, which were previously reported serologically in Tokat province, and the presence of GPGV by molecular methods. The presence of the newly reported GPGV in Turkey in the province of Tokat was tested for the first time in this study.

2. Material and Methods

2.1. Land surveys

In the summer of 2019, surveys were carried out in the vineyard areas in Central, Erbaa, Niksar, Zile, and Pazar districts, where viticulture is intensive in the province of Tokat. During the surveys, a total of 189 samples were taken from the young leaves and one-year-old shoots of vines showing virus symptoms in the vineyards. The collected samples were labeled in polyethylene bags and brought to the laboratory in an icebox and stored in the refrigerator at +4°C for a short time and at -20°C for a long time until testing. Guided sampling was done during the surveys, and the number of samples to be taken was determined according to Bora and Karaca (1970), considering the size of each vineyard.

2.2 Total RNA isolation

Isolation of RNA from collected samples grapevine sites was studied according to Foissac et al. (2001) protocol. Accordingly, 100 mg of each plant sample was weighed and 1 ml of extraction buffer (6 M guanidine thiocyanate containing 0.2 M sodium acetate, 25 mM EDTA, 1 M potassium acetate, 2.5% PVP-40, and 1% mercaptoethanol) was added, crushed in mortars and a new aliquot. After transferring to a sterile tube, 100 µl of 10% sodium lauryl sarcosyl solution was added, and then the tubes were incubated at 70 ºC for 10 minutes and then kept on ice for 5 minutes. After centrifugation in eppendorf tubes at 14,000 rpm for 10 minutes, 300 µl of supernatant was transferred to a new eppendorf tube containing 150 µl of ethanol, 25 µl of silica, and 300 µl of 6 M sodium iodide. This mixture was then incubated at room temperature for 10 minutes with intermittent shaking. After centrifuging at 6000 rpm for 1 min, after adding the supernatant, the pellets were washed with 500 µl of wash buffer (10 mM Tris-HCl containing 0.05 mM EDTA, 50 mM NaCl and 50% ethanol). After centrifugation at 6000 rpm, it was washed once again with washing buffer and then again subjected to centrifugation at 6000 rpm, the supernatants were removed and the tubes were dried by inverting on blotting paper. Then, 300 µl of RNase-free distilled water was added to them and incubated at 70 ºC for 4 minutes, then centrifuged at 14,000 rpm for 3 minutes, and the supernatant was transferred into a new eppendorf tube and stored at -20ºC until used in RT-PCR processes.

2.3 RT-PCR method

2.3.1 Complementary DNA (cDNA) synthesis

The RNAs obtained from the RNA isolated samples were removed from -20, and after incubation in a water bath at 65 °C for 5 minutes, they were placed on ice and kept on ice for 3 minutes. Complementary DNA (cDNA) was synthesised using 4 µl of total RNA, 4 µl 5X VS Reaction Buffer, 1 µl VitaScript™ Enzyme Mix, 11 µl nuclease-free dH2O in a 20 µl volume mix and kept at 25ºC for 10 min, followed by 42ºC for one hour and finally 85 ºC for 5 min.

2.3.2 PCR method

PCR processes were performed with virus-specific primers by using the cDNA which is obtained in the first step as a template (*Table 1*).

Table 1. Virus-specific primers, base sequences and binding sites used in the study for GVA, GPGV and SLRSV

TargetVirus/Primer	Primer Sequence	Region	Expected Amplicon Length	Reference
GVA-F	GACAAATGGCACACTACG	CP	429 bp	Minafra et al., 1992
GVA-R	AAGCCTGACCTAGTCATCTTGG			
SLRSV-F	CCTCTCCAACCTGCTAGACT	CP	497 bp	Martin et al., 2004
SLRSV-R	AAGCGCATGAAGGTGTAACT			
GPGV-F	GGAGTTGCCTTCGTTTACGA	CP	770bp	Beuve et al., 2015
GPGV-R	GTACTTGATTCGCCTCGCTCA			

The PCR temperature cycling conditions were as follows for GVA: initial denaturation at 95°C for 5 min; 35 cycles of denaturation at 94°C for 30 sec, annealing at 55°C for 30 sec, and elongation at 72°C for 1 min. The final cycle was followed by extension at 72°C for 10 min.; for SLRSV; initial denaturation at 95°C for 2 min; 35 cycles of denaturation at 94°C for 30 sec, annealing at 52 °C for 30 sec, and elongation at 72°C for 30 sec. and the final cycle was followed by extension at 72°C for 5 min.; for GPGV, initial denaturation at 94°C for 2 min; 35 cycles of denaturation at 94°C for 1 min, annealing at 59°C for 30 sec, and elongation at 72°C for 1 min. The final cycle was followed by extension at 72°C for 10 min.

2.4 Agarose gel electrophoresis studies

The PCR products obtained as a result of PCR performed with virus-specific primers were subjected to electrophoresis at 100 V for 1 hour in agarose gel prepared at a rate of 1.2% and containing 10 mg/ml ethidium bromide. At the end of the electrophoresis procedure, imaging was performed on the imaging device.

2.5 Phylogenetic Analysis by Maximum Likelihood

For phylogenetic studies, RT-PCR products of 11 isolates of the GVA, which gave positive results at the end of RT-PCR, were sent to the sequence. The obtained sequences were analyzed with the use of Maximum likelihood (ML) method in MEGAX computer program. The data were then compared with the reference isolates registered in the National Center for Biotechnology Information (NCBI) gene bank, and a phylogenetic tree was formed and the degree of relatedness was compared. Phylogenetic analyses were carried out using the maximum likelihood program (with 1000 bootstrap replicates) of MEGAX software (Kumar et al., 2018).

3. Results and Discussion

3.1 Survey results

For the study, a total of 189 vine samples were collected from different districts of Tokat in 2019 (Central n= 43, Erbaa n= 36, Niksar n=32, Pazar n=43 and Zile =35) (*Table 2*).

Symptoms in the samples that were taken; mosaic, yellowing, green veins - yellowing between veins, yellowing in veins - green color formation between veins, discoloration of veins, vein banding, deformities, redness, green

main veins of leaves - reddening between veins, necrotic spots, brown spots, mottling, swelling, inward curling of leaves, fan leaf formation and shrinkage, decrease in fruit set, formation of large and small grains, uneven coloration, growth retardation and general stunting were observed (*Figure1*).

Figure. 1. Some symptoms types observed in field surveys. a) It was tested for the possibility of multiple infections and was found to be infected with Grapevine Virus A. b) Positive band was obtained with reddish and yellowish colors Grapevine Virus A. c) The main veins of the leaves are green-reddening between the veins d) Veins green-yellowing between veins

3.2 RT-PCR Results

As a result of the RT-PCR test performed with GVA-specific primers GVA 1-F and GVA 1-R, bands of the expected size (430 bp) were obtained in a total of 81 samples (*Figure 2*). As a result of the RT-PCR test performed with GPGV-specific primers GPGV 2-F and GPGV 2-R, a band of the expected size (770 bp) was obtained in three samples (N-1, N-2, N-22) belonging to Niksar district (*Figure 3*).

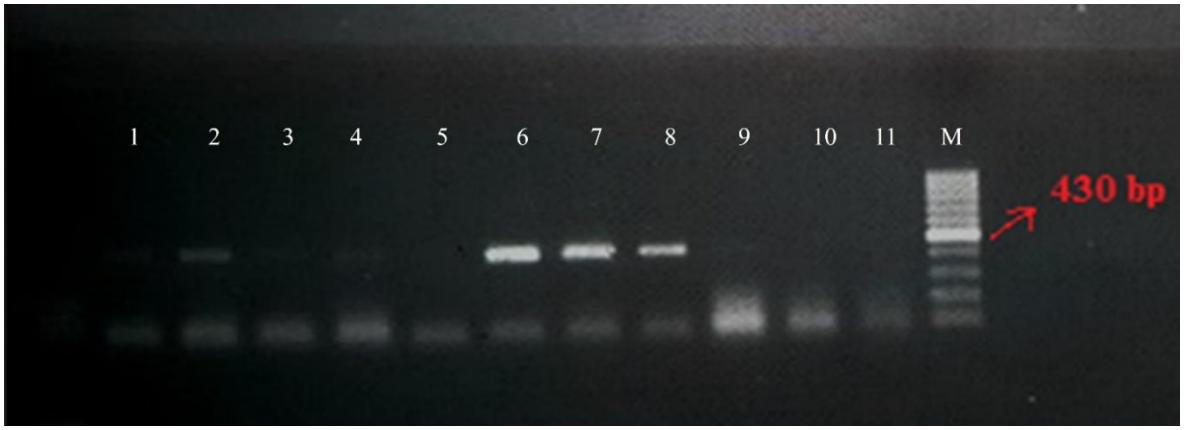

Figure.2. RT-PCR result of some isolates made with a primer specific to Grapevine Virus A. 1, 3, 4, 5, 9, 10: negative samples; 2: N2, 6: N22, 7: T42, 8: U24, 11: negative control, M: 100 bp ladder

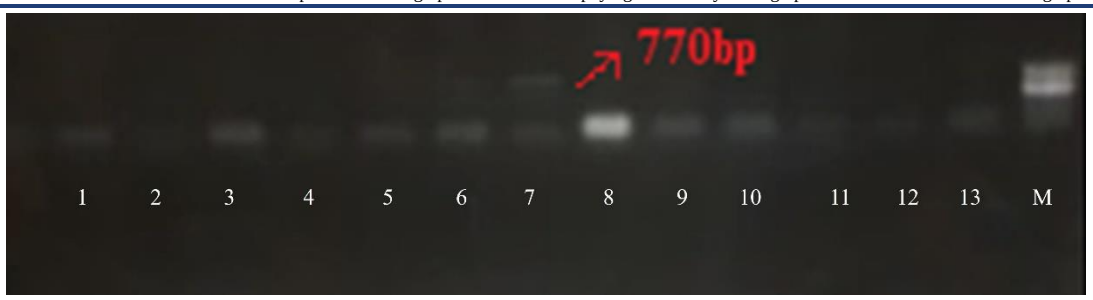

Figure.3. RT-PCR result of N-2 isolate with Grapevine pinot gris virus specific primer. M: 100 bp ladder, 13: Negative control, 7: N1.

A total of 189 samples taken from Central and its districts were tested for the presence of GVA, GPGV, and SLRSV viruses. Positive results were obtained in 81 of the 189 grapevine samples tested. Of the total 189 plant samples tested, 80 (42.32%) were found to be infected with GVA and 3 (1.58%) with GPGV. Mixed infections with GVA and GPGV were detected in two samples. It was determined that the most common virus in plant samples collected from Tokat Center and its districts was GVA, followed by GPGV. No sample infected with SLRSV was detected. The distribution of viruses detected in Tokat vineyard areas by districts is given below (*Table 2*).

Table 2. The number of samples collected from the Center and districts of Tokat province and the distribution of viruses detected in the vineyard areas by districts

DISTRICT	Collected and tested samples	Number of Infected Plants	GVA	GPGV	SLRSV
Center	43	14	14	-	-
Erbaa	36	25	25	-	-
Niksar	32	13	10	3	-
Pazar	43	19	19	-	-
Zile	35	12	12	-	-
Total infected sample		**83**	80	3	-
Total samples	**189**				

3.3 Phylogenetic and BLAST analyses results

In the study, phylogenetic analysis of CP sequences of GVA isolates obtained from this study and reference sequences of isolates available in NCBI databases were constructed.

Sequence information of the GVA CP region from Turkish isolates were submitted to GenBank, with accession numbers: N2 (OP434321), N22 (OP434322), T10 (OP434323), T2 (OP434324), T42 (OP434325), U29 (OP434326), Z14 (OP434327), Z26 (OP434328), D17 (OP434329), D27 (OP434330), and D7 (OP434331). As a result of the phylogenetic analysis performed with the sequence data of the CP region of 11 samples infected with GVA, the D-17 isolate obtained in the study showed similar branching with the USA isolate, while the other isolates showed close similarity to China, Portugal, and South Africa isolate and were grouped with Group I isolates (*Figure 4*).

The sequence analysis of GVA isolates showed that Turkish GVA isolates showed 82-95 nucleotide and 95-99% amino acid similarity among themselves and shared 92-99% sequence and 79-99% amino asit (a.a) similarity with reference isolates from different countries.

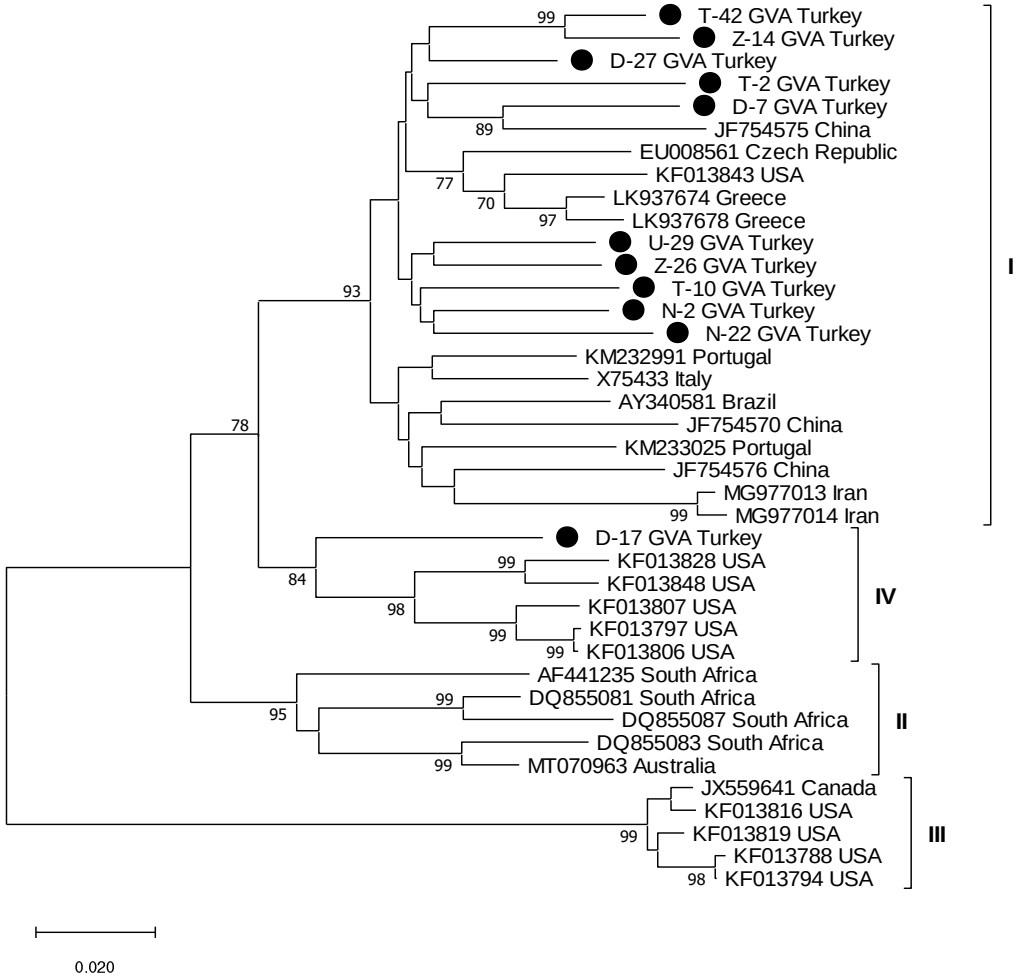

Figure 4. Phylogenetic tree constructed based on the partial nucleotide sequences of the CP gene of new Grapevine Virus A isolates and reference Grapevine Virus A isolates with the use of Maximum likelihood (ML) method. Turkish Grapevine virus A isolates are indicated using a black filled circle.

4. Discussion

Although Anatolia is an important grape producer in the world, it has been observed that viticulture has started to decline in the last 20-25 years. There are various factors among the reasons for this regression. One of them undoubtedly plants protection problems. Among the plant protection factors, virus diseases, which spread rapidly with the production materials and show their visible symptoms 4-5 years after the vineyard establishment, have a separate place and importance. Therefore, it is vital to take the necessary precautions with viruses early. Measures and determinations to be taken for the development of viticulture, which is done intensively in the province of Tokat, gain serious importance. Considering the damage caused by virus diseases in the province of Tokat, where viticulture is common, it is important to determine the presence of virus diseases that will cause damage in the vineyard areas with this study. Because, in the fight against viral diseases, it is primarily the identification of the viral agent.

GVA is a worldwide viral pathogen associated with Kober stem grooving and Shiraz diseases (Minafra et al., 2017). It causes grapevine stem pitting disease and noticeable stunting in grapes (Akbaş et al., 2008), and also is often associated with GLRaV in the field (Sabanadzovic, 2009). In our country where viticulture is common, the damage caused by virus diseases should not be ignored. Detection of its existence and measures to be taken are important to eliminate these adverse conditions.

In a study conducted by Soğukömeroğulları (2017), prevalence of GVA and GVB was investigated in autochthonous grape varieties throughout vineyards of TRC 1 region (Gaziantep, Adıyaman, Kilis) by serological and

biological methods. Total of 66 leaf and shoot samples from Gaziantep (5), Adıyaman (7) and Kilis (54) were tested for GVA and GVB in DAS-ELISA and Double antibody sandwich indirect (DASI-ELISA). Prevalence of GVA was 16 % at Adıyaman, 24 % at Kilis and 20 % at Gaziantep. GVA could not be detected in the samples taken from Adıyaman and Gaziantep, but it was found to be around 11.54% in Kilis.

In previous studies, CP sequence information of GVA has been reported by different researchers (Minafra et al., 1994; Anfoka et al., 2004; Alabi et al., 2014; Goszczynski et al., 2008; Goszczynski and Habili, 2012; Moradi et al., 2018). Firstly, GVA isolates have been grouped into three groups including I, II, and III by Anfoka et al. (2004) and Goszczynski and Habili (2012). After, Alabi et al. (2014) reported that based on phylogenetic analysis of CP sequences of GVA isolates collected from different wine grape cultivars, the GVA isolates were divided into four major clades: groups I, II, III, and IV. Balsac and Buzkan investigated molecularly the prevalence and genetic variability of GVA in autochthonous grapevine cultivars based on the analysis of its CP gene in two important grape regions: Eastern Mediterranean (EM) and Southeast Anatolia (SEA). they reported that RT-PCR revealed a high infection rate of GVA in two major viticultural areas, and high nucleotide and amino acid sequence similarity were seen between the Turkish GVA isolates and the reference isolates in group I and II. In this study, Turkish GVA isolates except for one isolate (D17) were grouped into group I, which include many isolates from different countries such as the USA, Macedonia, Iran, and China. The D17 isolate was grouped into new subgroup IV, which consists of USA, China and Greece isolates. According to the results of the phylogenetic analysis of CP sequences, Balsak and Buzkan (2021) reported that GVA isolates and cultivars in the same location were not phylogenetically related. Similary in this study, one isolate (D17) showed phylogeneticly difference from others.

In another study, Çiftçi et al. (2015) in the spring and autumn of 2014, they conducted field studies in grape growing areas in the Eastern and Southeastern Regions of Turkey. They were collected a total of 87 specimens in the spring and 123 specimens of vines showing signs of the virus in the fall and, were tested by using DAS-ELISA for the presence of GLRaV-1, GLRaV-2, GLRaV-3, GLRaV-4, GLRaV-5, GLRaV-6, GLRaV-7, GLRaV-9, Grapevine fanleaf nepovirus (GFLV), GFkV, GVA, Raspberry ringspot nepovirus (RpRSV), SLRSV, Tomato black ring nepovirus (TBRV), Arabis mosaic virus (ArMV), and also PCR was performed for Grapevine red blotch-associated virus (GRBaV) using the primer pairs designed in the study. The most common virus was GFLV (6.66%), followed by GLRaV 4-9 (3.80%), GLRaV 1+3 (3.81%), GFkV (1.43%) and GVA (0.95%).

Gazel et al. (2016) collected eighteen suspicious samples with leaf deformation and mottling symptoms that reduced fruit yield and quality and applied the RT-PCR test for GPGV. As a result of the test, they obtained the first report of GPGV in the grapevine in Turkey. The presence in the province of Tokat of GPGV, which newly reported in Turkey, was tested molecularly for the first time in this study but sufficient PCR product could not be obtained for the sequence analysis. More detailed studies are planned for the future.

In another study conducted by Turkmen (2020), shoots and leaves were collected from 418 vine plants in 2017 from vineyards in Amasya, Çorum and Tokat, and were investigated for the presence of GFLV and GPGV using RT-PCR methods. At the end of tests, the highest infection rate for GFLV was found in Tokat province, followed by Amasya and Çorum provinces at rates 48.45%, 24.32%, 13.18%, respectively. GPGV was detected only in Amasya and Tokat provinces at a rate of 8.11 % and 10.55 %, respectively. Based on the phylogenetic trees, all the GFLV isolates obtained in the study and 12 Iranian isolates have high similarity. According to sequences of movement protein region of all GPGV isolates obtained in this study, 3 other Turkey isolates and 2 Czech Republic isolates showed the highest similarity. On the other hand, according to coat protein sequences of GPGV isolates were closely grouped with the other Turkish isolates and Slovakian isolates. In the study, sequence results of GPVV isolates, which were positive as a result of RT-PCR, could not be obtained in the study, and it is planned to be done again in the future.

Although no infected samples were detected in the study of SLRSV, the risk of spreading in the region is high. For this reason, it is necessary to take measures to prevent the spread of viral factors and to raise the awareness of producers on this issue. It is also necessary to fight against vector nematodes that play a role in the transmission of this factor. Since other viruses, which are the subject of research, are carried by crustacean lice and mite species, it is necessary to fight vector insects.

5. Conclusions

In conclusion, viruses cause deformations in vine leaves and decrease in leaf quality, as well as damage to fruit. Chemical control against plant virus diseases cannot be eliminated like the fight against insects and fungal diseases.

For this reason, care should be taken to ensure that grafting materials such as scion and rootstock, which play an important role in the spread of GPGV, GVA, and SLRSV agents, are free of viruses, and more importance should be given to the necessary precautions in seedling production. Producers should be made aware of using certified vine samplings. Since GVA and GPGV viruses are transmitted by mechanical means, tools and equipment used in vineyards should be disinfected and protective measures should be taken in the struggle, especially infected vines should be removed. It is important to use molecular methods for the identification of GVA-infected and non-infected vines. In this study, phylogenetic analysis of Turkish GVA isolates was performed for the first time.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

The Effect of Different Fertilization Frequency on Some Nutrient Content of Palm Plant Grown in Peat Swamp

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Abstract

The lack of suitable land (S1) for oil palm plantations is the reason for the current use of marginal land (S3) in oil palm plantations, both for companies and smallholders. Peat swampland has good potential if the care and fertilization of plants is carried out according to the standards according to the conditions of the land. Peat swampland has high acidity, and land conditions are often flooded. Application of fertilizer in a timely manner and the right dose is one of the keys to the success of oil palm plantations. This study aimed to determine the effect of the frequency of fertilizer application on the nutrient content of oil palm leaves. There were three fertilization treatments, namely 1) 0.6 kg/tree was applied once a month, 2) 1.8 kg/tree was applied once per three months, and 3.6 kg/tree was applied once per six months. Data were analyzed using a completely randomized design. The results showed that the frequency of fertilization significantly affected the nutritional content of oil palm leaves. The average nutrient content of fertilization with a frequency of six months has the lowest nutrition compared to other frequencies. The best frequency of fertilization is 0.6 kg/tree, which is applied every month. Fertilization on peatlands that is carried out regularly and in a balanced dose is more important than the application of high doses of fertilizer with a long frequency of fertilization. This is related to palm oil feeding root distribution, which is limited to a swamp depth of 0-60 cm.

Keywords: Oil palm, Plant nutrition, Peatland, Frequency of fertilization, Peat swamp.

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1. Introduction

Peat swampland in Indonesia is quite extensive, reaching 20.6 million ha or 10.8% of Indonesia's land area. Most of the peat swampland is located on four large islands: Sumatra 35%, Kalimantan 32%, Sulawesi 3%, and Papua 30% (Wetland International, 1990). Naturally, peat swamps always experience inundation so their use for crops can be done by lowering the groundwater level. It is also intended that the plant roots above it are not flooded to absorb nutrients more optimally. Peat swampland has a low pH, so the absorption of nutrients Nitrogen, Phosphorus, Potassium, Magnesium in plants is not optimal (Amirrullah et al., 2017). However, with proper handling, this marginal land can be developed into agricultural land. One of them is oil palm plantation land. The use of peat swampland for oil palm plantations is increasing in Southeast Asia (Charters et al., 2019). This marginal land use is also due to the increasingly limited mineral land for oil palm plantations. The use of marginal land for oil palm development is carried out by companies and smallholders (Anamulai et al., 2019).

Basically, oil palm plants can grow on peat swampland that is poor in nutrients. However, fresh fruit bunches (FFB) production depends on land and plant management. According to (Mangoensoekarjo and Semangun, 2003), FFB production will decrease by 20% if planted on peatland. Just like other plants, oil palm plants need adequate nutrients for vegetative and generative growth. The research results by (Matana and Mashud, 2015) indicated that the response of oil palm plants to fertilization was different for each type of plant.

Oil palm plants need to macro plant nutrient elements such as Nitrogen, Phosphorus, Potassium, and Magnesium. The research results by Nurhayati et al. (2016) showed that the application of macro and micro fertilizers in tidal land with a dose of 5 kg macro + 5 kg micro per tree resulted in FFB production of 30.62 tons/ha/year. Thus, applying the right fertilizer on marginal land will also be able to produce good production. In addition to the dose, the frequency of fertilizer application also significantly affects the vegetative growth of oil palm plants. The frequency of fertilizer application often shows good vegetative development (Hayata et al., 2018; Syafitri et al., 2007). Previous research has shown that fertilization increases significantly yields in forage and dry matter in both floodplain and grassland areas (Altın et al., 2010).

The need for macronutrients in oil palm plants increases according to the age of the plant (Henson and Dolmat, 2003). However, the absorption of nutrients in plants depends on land conditions (Chrisye, 2020; Fajarditta et al., 2012). In bad situations, if the absorption of plants lacks nutrients, there will be an abortion of female flowers or the formation of many male flowers. If female flowers are reduced, then production will decrease. So a different technique is needed so that the nutrients can be absorbed properly. One of them is the frequency of fertilizer application. Good nutrient absorption will be seen from the nutrient content in the leaves. Thus, this study is expected to determine the frequency of the most good fertilizer application for oil palm plantations in peat swampland.

2. Materials and Methods

This research was conducted on 5 year old oil palm plants. This study was an experimental study using a completely randomized design (CRD) with 3 treatments with fertilization frequency repeated 5 (five) times. The fertilizer used is a compound fertilizer (NPKMg) containing 12% Nitrogen, 12% Phosporus, 17% Potassium and 2% Magnesium. The treatments given were A) a dose of 0.6 kg/tree once a month B) a dose of 1.8 kg/tree every 3 months and C) a dose of 3.6 kg/tree every 6 months. The analysis of the significant difference test between treatments used the T test by comparing the data before and after the treatment.

3. Results and Discussion

Table 1 is the result of analyzing the nutritional content of oil palm leaves after fertilization treatment based on frequency (fertilization time). According to Fairhurst and Mutert (1999), nutrients in oil palm leaves are categorized as deficiency if Nitrogen < 2.3%; Phosphorus < 0.14% ; Potassium < 0.75% and Magnesium < 0.20%. The data in *Table 1*, when compared with the standard nutritional content of oil palm plants, showed potassium deficiency in all experimental plants, both at the frequency of fertilization every month, three months and every six months. However, in magnesium nutrition, all experimental plants had sufficient nutrients. When viewed as a whole and the average nutritional content, fertilization carried out at a frequency of six months has the lowest nutritional value compared to other frequencies.

Table 1. Results of laboratory analysis of nutrient content in leaves after treatment

Frequency	% Nutrition			
	Nitrogen	**Phosphorus**	**Potassium**	**Magnesium**
1 month	2.26*	0.15	0.30*	0.62
	2.69	0.18	0.26*	0.38
	2.96	0.12*	0.20*	0.50
	2.78	0.17	0.46*	0.47
	2.43	0.16	0.54*	0.62
Average	2.62	0.15	0.35	0.51
3 Month	2.43	0.16	0.66*	0.53
	2.54	0.16	0.69*	0.50
	2.68	0.17	0.62*	0.63
	2.65	0.18	0.69*	0.52
	2.60	0.18	0.69*	0.52
Average	2.58	0.17	0.67	0.54
6 Month	2.44	0.15	0.44*	0.63
	2.55	0.16	0.36*	0.47
	2.15*	0.14*	0.64*	0.50
	1.90*	0.12*	0.31*	0.58
	1.67*	0.15	0.46*	0.31
Average	2.14	0.14	0.44	0.49

The sign (*) indicates low nutrition when compared to nutritional standards in oil palm plantations
Analysis Nitrogen used Kjedahl with Spectrophotometer
Analysis Phosphorus used Dry ashing # HNO# with Spectrophotometer
Analysis Potassium used Dry ashing# HCl # with AAS
Analysis Magnesium used Dry ashing# HCl # with AAS

Table 2. Significant difference test of fertilizer frequency

Frequency	% Nutrition			
	Nitrogen	**Phosphorus**	**Potassium**	**Magnesium**
1 Month	2.624	0.156	0.352	0.518
3 Month	2.580	0.170	0.670*	0.540
6 Month	2.142*	0.144	0.442	0.498

* : there is a significant difference in the frequency of fertilization on the nutrient content in the LSD significant difference test (α = 5%)

Based on the results of the t test analysis (*Table 2*), shows that the effect of fertilization frequency on the nutrient content of oil palm leaves. The analysis results showed that there was a significant effect on the frequency of fertilization on the nutrient content. Significant differences occurred in nitrogen nutrition in the frequency of fertilization every six months. Meanwhile, the potassium nutrition was significantly different in the frequency of three months of fertilizer. Overall, the best nutritional value occurred at the frequency of fertilization carried out per month.

Fertilizer application on S3 land should use compound fertilizer at a 6 kg/tree/year (Goh and Buloh, 2005; Mangoensoekarjo and Semangun, 2003; Sakata et al., 2015). The chemical and physical properties of the soil affect the absorption of nutrients in plants. According to Bornø et al. (2019) and Rehman et al. (2020), the soil's grip that can hold water can increase the absorption of good nutrients for plants so that their growth is better.

Tables 1 and 2 show that the frequency of fertilization once a month is considered to have better nutrition than other treatments. According to Goh and Buloh (2005), Mangoensoekarjo and Semangun (2003), and Noviana and Ardiani (2020), regular fertilization on peatlands and balanced doses is more important than the application of high amounts of fertilizer with infrequent fertilization frequency. This is because the distribution of palm oil feeding roots is limited to a depth of 0-60 cm.

N levels in peat soils are relatively high ranging from 1% - 2% due to weathering of plants that become an organic matter on the top of the soil (Noor, 2016). However, the addition of N fertilizer is still recommended with

the right dose and frequency. In general, the peatlands in the study area have an acidity (pH) of 4-5.5. This can result in inhibited absorption of very low potassium nutrients. Based on research (Ollagnier, 1987; Roca and Vallejo, 1995; Römheld and Kirkby, 2010) high Ca content in soil results in low plant response to K fertilization. In addition, chemical fertilizers are very important for high and economical yield levels (Turhan and Özmen, 2021).

4. Conclusions

The frequency of fertilization applied to peatlands significantly affects the nutrient content of oil palm leaves. The average nutrient content of fertilization with a frequency of six months has the lowest nutrition compared to other frequencies. In contrast, the best nutrition is found in fertilization with a frequency of once a month. It is recommended that fertilizer application on S3 land be carried out routinely and balanced compared to the application of high doses of fertilizer with infrequent frequency (6 months).

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Comparative Investigation of Drying and Quality Characteristics of Organic and Conventional Black Carrots Dried by Intermittent Microwave and Hot Air*

Kesikli Mikrodalga ve Sıcak Hava ile Kurutulan Organik ve Konvansiyonel Siyah Havuçların Kuruma ve Kalite Özelliklerinin Karşılaştırmalı Olarak İncelenmesi

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Abstract

The quality of agricultural crops is influenced by growing conditions and post-harvest processes, including drying. Moreover, the total phenolic and total antioxidant content in the product's structure and composition can be either positively or negatively affected by the heat treatments applied during drying. Additionally, the specific growing conditions and methods of water removal can lead to the development of distinct drying characteristics. There was no study comparing the drying kinetics and quality parameters of organic (OBC) and conventional (CBC) black carrot in the literature studies. In this study were aimed that mathematically modelling the drying kinetics for OBC and CBC with IMW (150, 300, 450 W) and HA (60, 70, 80°C), determining their differences and evaluating the effects of methods on quality properties. The results showed that L* and ΔE values of the final products increased significantly by increasing the power and temperature levels applied during drying and the powder samples were lighter in color compared to the fresh samples. The total phenolic and total antioxidant capacity values were higher in fresh OBC samples compared to the conventional variety. This result shows that OBC is superior to the CBC in terms of higher total phenolic and total antioxidant content. The activation energy (E_a) values of OBC and CBC dried by IMW and HA were calculated as $8.41x10^{-3}$; $8.40x10^{-3}$ Wg^{-1} and 25.50; 19.72 kJ mol^{-1}, respectively. The Logistic and Verma were the best fit models for describing IMW and HA drying kinetics, respectively. The samples obtained with IMW drying, which resulted in a shorter drying time, were more effect in terms of preserving and increasing the total phenolic and antioxidant content compared to dried samples with HA. The results showed that that the temperature/power levels applied to the products during the drying process, thus the drying times and the methods of removing moisture from the product are effective in the preservation of the total phenolic components.

Keywords: Drying kinetics, Activation energy, Modelling, Total phenolic, Antioxidant capacity

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Özet

Tarımsal ürünlerin kalitesi, yetiştirme koşullarından ve kurutma gibi hasat sonrası işlemlerden etkilenebilir, ayrıca ürün yapısındaki toplam fenolik ve toplam antioksidan içeriği ve bileşimi de kurutma sırasında uygulanan ısıl işlemlerden olumlu veya olumsuz yönde etkilenme potansiyeline sahiptir. Ayrıca, yetiştirme koşulları ve suyun üründen uzaklaştırılma şekli farklı kuruma özelliklerinin gelişmesine neden olabilir. Literatür çalışmaları arasında organik (OBC) ve konvansiyonel (CBC) siyah havucun kurutma kinetiği ve kalite parametrelerinin karşılaştırıldığı bir çalışmaya rastlanmamıştır. Bu çalışmada, OBC ve CBC materyallerinin kesikli mikrodalga (IMW) (150, 300, 450 W) ve sıcak hava (HA) (60, 70, 80°C) yöntemleri ile kuruma kinetiğinin matematiksel olarak modellenmesi, farklılıklarının belirlenmesi ve yöntemlerin kalite özelliklerine etkilerinin değerlendirilmesi amaçlanmıştır. Sonuçlar, kurutma sırasında uygulanan güç/sıcaklık seviyelerinin artmasıyla nihai ürünlerin L* ve ΔE değerlerinin önemli ölçüde arttığını ve toz numunelerin taze numunelere göre daha açık renkli olduğunu göstermiştir. Taze OBC örneklerinde toplam fenol ve toplam antioksidan kapasite değerleri konvansiyonel çeşide göre daha yüksek bulunmuştur. Bu sonuç, OBC'nin toplam fenolik ve toplam antioksidan içeriği açısından CBC'den daha üstün olduğunu göstermektedir. IMW ve HA ile kurutulan OBC ve CBC'nin aktivasyon enerjisi (E_a) değerleri sırasıyla $8.41x10^{-3}$; 8.40x10-3 Wg^{-1} ve 25.50; 19.72 kJ mol^{-1} olarak belirlenmiştir. Logistic ve Verma modellerinin, sırasıyla IMW ve HA kurutma kinetiğini tanımlamak için en uygun modeller olduğu saptanmıştır. Daha kısa kuruma süresi ile sonuçlanan IMW kurutma ile elde edilen numunelerde, HA ile kurutulmuş numunelere göre toplam fenolik ve antioksidan içeriğin korunması ve arttırılması daha etkili olmuştur. Sonuçlar, kurutma işlemi sırasında ürünlere uygulanan sıcaklık ve güç seviyelerinin, dolayısıyla kuruma sürelerinin ve üründen nemi uzaklaştırma yöntemlerinin toplam fenolik bileşenlerin korunmasında etkili olduğunu göstermiştir.

Anahtar Kelimeler: Kurutma kinetiği, Aktivasyon enerjisi, Modelleme, Toplam fenolik, Antioksidan kapasite.

1. Introduction

Drying, which is also classified as a food preservation method, can be defined as the process of removing excess water from the product, which causes the development of negative properties in the products after a certain period of time. The way of water removed from food products (Esturk et al., 2011), drying methods (Soysal, 2004), drying temperature or power levels (Arslan, 2021), growing conditions of products (Asami et al., 2003; Arslan et al., 2020a; Guilherme et al., 2020), maturity stages (Soysal et al., 2018), thickness (Sadin et al., 2014), air flow rate (Velić et al., 2004), drying time (Soysal, 2004; Arslan et al., 2021), properties of the material, freshness and many other factors causes the development of different quality characteristics in final products. Determining drying conditions that affect the quality of the final products as positively or negatively and to verify the effectiveness of the conditions with experimental methods are important.

By using modern drying methods, a higher quality and more valuable final products in terms of health is obtained compared to traditional methods (Soysal, 2004). In hot air (HA) drying, there is a gradual transfer of heat from the material surface to the interior due to the temperature difference between the hot surface and the colder interior of the material (Arslan et al., 2020b). In the microwave (MW) drying method, the electromagnetic field affects the whole material and the water molecules in the material are directly targeted (Soysal et al., 2006), thus a selective heating is performed resulting in a shorter drying time. As a result of the application of continuous MW energy, some negative quality characteristics such as burns in the material and hardening on the product surface (Soysal, 2004) develop as a result of high temperature/power applied to the dried material. With intermittent microwave (IMW) drying, the development of undesirable properties is reduced and more homogeneous heat and mass transfer is allowed (Soysal, 2009).

The cultivation of agricultural practices can affect the phytochemical content, structure, taste, aroma, color and thus drying properties of the products (Asami et al., 2003; Keskin et al., 2021a; Arslan, 2022). Bickel and Rossier (2015) reported that organic products are more nutritious than conventional varieties. Guilherme et al. (2020) stated that chlorogenic acid, caffeic acid and rutin were found in higher levels in red organic peppers. Arslan (2021) reported that organic black carrot (OBC) as fresh and dried by IMW are superior to its conventional (CBC) variety in terms of total phenolic and total antioxidant capacity. Phenolic compounds in fruits and vegetables are natural antioxidants that have the ability to reduce and remove the negative properties of free radicals (Sonmezdag, 2015). During the application of heat treatments, the nutritional value of the food decreases significantly due to the destruction of heat-sensitive phenolic components (Choi et al., 2006). However structure and composition of the foods and the applied heat treatments may cause an increase or decrease in the amount of phenolic compounds (Sakač et al., 2011), antioxidants (Meral, 2016) and color (Aktaş et al., 2013; Keskin et al., 2019; Arslan et al., 2023) properties. Keskin et al. (2021b) found that the highest amounts of phenolic were in the black carrot samples dried by HA and IMW compare to freeze drying. Therefore, evaluating of the effects of drying methods and applied temperature/power levels on the total phenolic compounds naturally found in food and the total antioxidant capacity are important.

Black carrot (*Daucus carota* L. ssp. *sativus* var. *Atrorubens* Alef.) commonly is used in powder form as a colouring additive, dietary fiber source, phenolic and antioxidant component of different dried and liquid products (Janiszewska et al., 2013) and have a high potential as a food colorant due to their low toxicity (Ersus & Yurdagel, 2007). The quality of black carrot obtained by applying various cultivation methods such as organic or conventional is likely to be affected by these conditions. Therefore, it may be beneficial for the sector to determining the drying resistance of the product types for the same drying power/temperature and to determine the effects of these conditions on product quality. Further, evaluation of the effects of drying methods on drying kinetics, quality and color parameters can be useful in terms of predicting of final product quality. In the literature studies, there was no studies comparing the drying kinetics, color parameters and quality of OBC and CBC of dried by IMW and HA drying methods. Therefore, this study was carried out to evaluating effects of drying OBC and CBC samples at different power and temperature levels with IMW and HA, their drying kinetics, moisture diffusion characteristics, mathematical models, effects on color, total phenolic and antioxidant capacities. This study is the first research in literature which the drying characteristics and pre- and post-drying quality parameters of organic and same variety conventional black carrots are examined.

2. Materials and Methods

2.1. Black carrot samples

OBC and CBC samples (Eregli local cultivar) were obtained from open field conditions (Eregli, Konya Turkey) (37.7458°N, 33.9254°E). Harvested samples were classified according to their size and color properties, they were stored in the refrigerator at +4°C until drying stage. The initial moisture content determined by standard oven method (103°C for 24 h) of the OBC and CBC samples were about 87.8% and 88.1%, respectively.

While preparing the samples for the drying stage, they were firstly washed with tap water, removed moisture with filter paper and grated by using a grater to provide a certain thickness level (Tefal, MB753538). The samples were spread homogeneously on the glass table (diameter: 30 cm, mass: 1150 g) surface and the product mass was adjusted as approximately 250 g. Average half layer thickness of the samples over the glass tray surface (6.4±0.50 mm) and average grated material slice thickness (1.4±0.13 mm) were measured.

2.2. Intermittent microwave drying process

A lab-scale (MD 1605, Beko, Istanbul, Turkey; nominal power: 2.45 GHz, 900 W) microwave oven was used in the IMW drying experiments (Actual power: 735.8±8.12 W; the size of MW oven cavity: 22x35x33 cm). The experiments were carried out by varying the IMW open (T_{on}) and close (T_{off}) times at different power levels (150, 300 and 450 W) and controlled by a Programmable Logic Controller (PLC) according to the method applied by Arslan et al. (2020a) (airflow speed: 1.5 ms^{-1}).

2.3. Hot air drying process

The HA consists of three main units, an electrical resistance based air heater, a radial fan and a drying chamber. With the software created by using the Arduino UNO card, the heating resistors were automatically turned off when the temperatures in the cabinet exceed the determined level (60, 70, 80°C) and automatically turned on when the temperature falls below the determined temperature levels, and the determined drying temperatures are obtained (airflow speed: 1.25 - 1.50 ms^{-1}).

The drying procedure was repeated five times at each of the three IMW power (OBC: 15; CBC: 15) and temperature (OBC: 15; CBC: 15) levels, and a total of 60 drying experiments were performed.

Digital balance (Sartorius TE3102S Germany, 3100, accuracy: 0.01 g) was placed under the rotating glass tray to measure the mass of materials and the temperature in each drying method were recorded one minute intervals. All experiments were lasted when the samples reached a moisture level of about 0.10 kg [H2O] kg^{-1} [DM]. Fresh and dried black carrot samples was given in *Figure 1*. The dried samples were powdered with an electric grinder (BlueHouse, BH258CG).

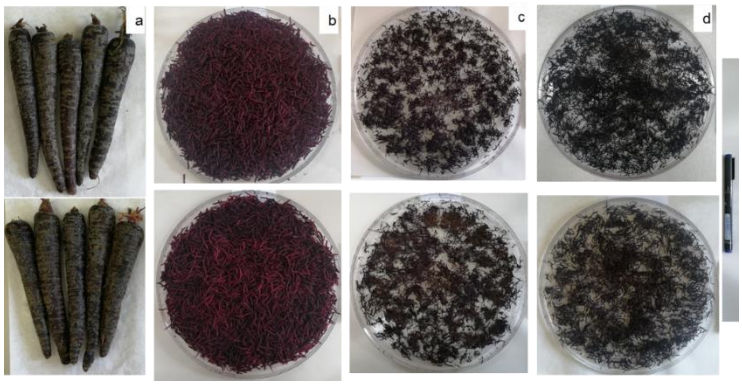

Figure 1. Organic (above), conventional (below) black carrot samples; whole (left) (a), fresh grated samples (b), dried by intermittent microwave (c) and dried by hot air (d)

2.4. Analysis of color parameters

The color properties of carrot samples was measured with a handheld colorimeter (Minolta CR - 400, Osaka, Japan) using the CIE L*a*b* color model. The meanings of L*, a* and b* parameters are color brightness, red-

green and yellow-blue, respectively. The color difference (ΔE*) and was calculated as according to Soysal et al. (2018).

2.5. Determining of total phenolic and total antioxidant capacity

The total phenolic content of the samples was determined according to the method applied by Singleton and Rossi (1965). 1 ml of each sample extract was mixed with 60 ml of distilled water, 5 ml of Folin-Ciocalteu solution and 15 ml of sodium bicarbonate solution and left for 2 hours at 25°C. Total phenolic content was measured at 765 nm with a UV-VIS field spectrophotometer (Agilent, Cary 60 UV-VIS, USA). The amount of phenolic compound, which is the gallic acid equivalent of the measured absorption value, was calculated from the equation of the standard curve prepared with gallic acid. Total phenolic content was calculated in "mg gallic acid/kg".

There are different methods for the analysis of total antioxidant capacity of the samples. Although each method has advantages and disadvantages, the success of the analysis method to be chosen may vary according to the material kinds. For example, the DPPH (2,2-diphenyl-1-picrylhydrazil) method; since it is sensitive to light, oxygen and pollution factors, there may be certain limitations in the use of this method (Mot et al., 2011). Therefore, the antioxidant activities of the samples were determined according to DPPH and ABTS (2,2'-Azino-bis 3-ethylbenzothiazoline-6-sulfonic acid) methods.

Evaluating of the antioxidant capacity for DPPH and ABTS were determined at 515 nm (Brand-Williams et al., 1995) and 734 nm (Saafi et al., 2009) in the UV-VIS field spectrophotometer, respectively. Absorbance values were calculated with the Trolox standard slope chart and the results were determined in µmol/100g Trolox.

2.6. Mathematical modeling of drying curves

The data were fitted to various drying models to determine the best fitting drying equation. In the evaluation, the equilibrium moisture content (M_e), was assumed to be zero, and the Moisture ratio (MR) were simplified as M/M_0 (Doymaz and Pala, 2002). The equations of the models are calculated as Arslan et al. (2020a).

Where,

M_e: Equilibrium moisture content (kg [H_2O] kg^{-1} [DM]),

M: The moisture content at any time during drying (kg [H_2O] kg^{-1} [DM])

M_0: The initial moisture (kg [H_2O] kg^{-1} [DM]) correspond to their meaning.

Nonlinear regression models were applied with Sigma Plot (10.0) program (Version 12; Systat Software, San Jose, CA, USA). The statistical values of R^2 (the coefficient of determination), RSS (residual sum of squares) (Equation 1) and SEE (standard error of estimate) (Equation 2) were calculated to select the best models. These parameters were computed as follows:

$$RSS = \sum_{i=1}^{N} (MR_{exp,i} - MR_{Pre,i})^2 \quad \text{Eq. (1)}$$

$$SEE = \sqrt{\frac{\sum_{i=1}^{N} (MR_{exp,i} - MR_{pre,i}}{N - 2}} \quad \text{Eq. (2)}$$

In equations; $MR_{exp,i}$: experimental drying rate and $MR_{pre,i}$: estimated drying rate and N represents the number of data.

2.7. Effective diffusivity and activation energy

The effective moisture diffusivity (D_{eff}) was calculated with Equation 3 using the second Fick's diffusion equation given below (Crank, 1975):

$$MR = \frac{M - M_e}{M_0 - M_e} = \frac{8}{\pi^2} \sum_{i=0}^{\infty} \frac{1}{(2i+1)} \exp\left[\frac{(2i+1)^2 \pi^2 D_{eff}\, t}{4L^2}\right] \quad \text{Eq. (3)}$$

In equation, D_{eff}, L, i and t values represent the effective moisture diffusivity (m^2s^{-1}), half thickness of the samples layer over the glass tray surface (m), positive integer and time (s), respectively. Equation 3 is simplified as in Equation 4 (Wang et al., 2007):

$$\ln(MR)\ \frac{8}{\pi^2} - \frac{\pi^2 D_{eff}}{4L^2} t \qquad \text{Eq. (4)}$$

The D_{eff} values, were calculated by plotting experimental ln(MR) data against drying time, so the plot provides a straight line with a slope as $K=\pi^2 D_{eff}/4L^2$.

In the study, the D_{eff} values, on the ratio of applied IMW power to fresh sample mass were characterized with an Arrhenius-type exponential model Equation (Dadali et al., 2007) (Equation 5) for IMW method.

$$D_{eff}=D_0 \exp(-E_a\ m/P_a) \qquad \text{Eq. (5)}$$

Where, E_a is activation energy (Wg^{-1}), P_a is applied IMW power and m is mass of initial fresh samples. Then, the E_a was computed from the slope of the Equation 5 by plotting $\ln(D_{eff})$ versus m/P_a.

The HA temperature dependency of the D_{eff} was predicted by using an Arrhenius type equation (Doymaz and Ismail, 2011) (Equation 6) for HA method:

$$D_{eff}=D_0 \exp(-E_a/RT) \qquad \text{Eq. (6)}$$

Where, E_a is activation energy (kJ mol^{-1}), R is the universal gas constant ($8.3143x10^{-3}$ kJ mol^{-1}), T is applied absolute temperature (K). Then, the E_a was calculated from the slope of the Equation 6 by plotting $\ln(D_{eff})$ versus 1/T ($K_1=E_a/R$) for HA.

2.8. Statistical analysis

18 Fresh (OBC: 9; CBC: 9) and 60 dried-powdered OBC (HA: 15; IMW: 15) and CBC (HA: 15; IMW: 15) samples (three power and three temperature levels multiplied by five drying experiments) were included in color analysis. The effects of drying power and temperature levels on the color of dried-powdered OBC and CBC were examined with statistical software (SPPS, v.17, IBM, NY, USA) using one way of variance (ANOVA) and the means compared with Duncan's test ($p<0.05$).

The effect of drying power and temperature levels on the total phenolic (OBC: 3, CBC: 3) and total antioxidant (for DPPH and ABTS) capacity results of dried 6 OBC (HA: 3; IMW: 3) and 6 CBC (HA: 3; IMW: 3) were examined with ANOVA and their means compared with Duncan's test ($p<0.05$). Fresh OBC and CBC samples results of total phenolic and total antioxidant capacity were compared with the values of dried samples in the same analysis.

3. Results and Discussion

3.1. Effect of drying methods on color properties

Information of color parameters of OBC and CBC materials, fresh and dried by IMW and HA and after powdered, are given in *Table 1* and *Table 2*, respectively. The means of L*, a* and b* color parameters of fresh OBC and CBC were calculated as 25.48±0.48, 4.31±0.87, 0.884±0.28 and 21.35±0.76, 5.15±1.21, 1.91±0.38, respectively. The mean L* and b* value differences of fresh samples were significant ($p<0.001$). The color brightness (L*) and color difference (ΔE*) values of the final product were increased significantly increasing with the applied IMW power and HA temperature levels during drying and the dried-powdered samples were lighter in color compared to the fresh samples ($p<0.05$). The a* values of samples dried by IMW were significantly higher than the fresh ones ($p<0.05$) and decreased with increasing power level. Consequently, statistical analysis showed that applied temperature and power levels were a crucial factor on color parameters of the powdered carrots. The color of carrot samples dried at high applied temperature (70, 80°C) and power levels (300 W, 450 W) were comparatively brighter and more vivid blueness-red and increase of applied temperature levels.

Research findings were compared with literature studies. Similarly, Demiray (2015) determined that the b* value was significantly affected by the drying methods and conditions during the drying process of carrots ($p<0.05$). Polat et al. (2022) investigated that dried by convective and microwave drying on color properties of black carrot pomace and founded that convective drying resulted in higher L* and ΔE values but lower a* and b* values compared to dried samples by MW drying. Contrary to the results of this study, Talih et al. (2017) reported that the L* of the black carrot powders decreased with applied increasing MW powers. Keskin et al. (2021b)

founded that HA and IMW drying of black carrot samples resulted in a decrease in the b* value while increasing the L* and a* values.

Table 1. Color parameters of samples fresh and dried with intermittent microwave powers

Parameters	Product	Fresh	Dried at 150 W	Dried at 300 W	Dried at 450 W
L*	OBC	25.48±0.48^{b}	36.13±0.60^{c}	37.95±0.41^{d}	39.94±0.40^{e}
	CBC	21.35±0.76^{a}	39.51±0.95^{e}	41.97±0.50^{f}	44.70±0.45^{g}
a*	OBC	4.31±0.87^{a}	15.19±0.60^{f}	14.48±1.04^{ef}	12.20±0.66^{c}
	CBC	5.15±1.21^{a}	13.82±1.01^{de}	12.80±1.25^{cd}	10.72±1.10^{b}
b*	OBC	0.88±0.28^{c}	-0.48±0.40^{a}	-0.56±0.17^{b}	4.40±1.29^{e}
	CBC	1.91±0.38^{d}	-0.38±0.11^{b}	1.71±0.29^{d}	7.77±1.80^{f}
ΔE	OBC	-	15.42±0.44^{a}	16.17±0.70^{ab}	16.90±0.36^{b}
	CBC	-	20.72±0.95^{c}	22.50±0.82^{d}	25.35±0.60^{e}
Total Phenolic	OBC	903.0±0.87^{c}	1246.0±1.17^{f}	1075.9±0.56^{d}	1752.5±1.77^{h}
(mg/100g GAE)	CBC	865.8±0.58^{b}	732.5±1.84^{a}	1205.4±2.29^{e}	1346.3±0.72^{g}
AA, DPPH	OBC	427.4±5.87^{bc}	645.5±15.98^{d}	462.3±5.02^{c}	664.5±13.01^{d}
(µmol Trolox/100 g)	CBC	269.9±0.21^{a}	287.1±25.10^{a}	406.1±10.04^{b}	796.5±41.30^{e}
AA, ABTS	OBC	314.3±5.59^{b}	772.3±4.38^{e}	734.9±35.50^{e}	853.3±18.81^{f}
(µmol Trolox/100 g)	CBC	309.8±13.86^{b}	257.0±15.13^{a}	615.9±2.76^{c}	681.0±4.70^{d}
Drying Time (min)	OBC	-	103.0±0.0^{a}	50.0±0.0^{b}	35.0±0.0^{c}
	CBC	-	100.0±0.0^{a}	50.0±0.0^{b}	35.0±0.0^{c}

(OBC: Organic; CBC: Conventional; GAE: Gallic Acid Equivalent). Different letters on the same two rows for each parameter indicate that the difference between the means is significant (p<0.05).

Table 2. Color parameters of samples fresh and dried with hot air temperatures

Parameters	Product	Fresh	Dried at 60°C	Dried at 70°C	Dried at 80°C
L*	OBC	25.48±0.48^{b}	37.23±0.83^{c}	39.38±0.21^{d}	41.00±0.44^{e}
	CBC	21.35±0.76^{a}	39.22±0.30^{d}	40.39±0.74^{e}	42.91±1.18^{f}
a*	OBC	4.31±0.87^{a}	14.65±0.46^{e}	13.48±0.74^{cd}	13.97±0.40^{de}
	CBC	5.15±1.21^{a}	12.29±0.22^{b}	13.00±0.63^{bcd}	12.75±0.54^{bc}
b*	OBC	0.88±0.28^{c}	0.49±0.05^{c}	-0.35±0.13^{b}	-1.70±0.05^{a}
	CBC	1.91±0.38^{d}	3.58±0.20^{f}	2.05±0.49^{e}	0.95±0.05^{d}
ΔE	OBC	-	15.70±0.80^{a}	16.71±0.45^{b}	18.50±0.51^{c}
	CBC	-	19.80±0.32^{d}	21.10±0.25^{e}	23.37±1.21^{f}
Total Phenolic	OBC	903.0±0.87^{c}	878.2±0.35^{d}	1028.4±1.45^{g}	1111.9±1.04^{h}
(mg/100g GAE)	CBC	865.8±0.58^{b}	517.8±1.28^{a}	698.9±4.52^{b}	993.2±1.29^{f}
AA, DPPH (µmol	OBC	427.2±5.87^{bc}	289.0±12.72^{bc}	330.9±7.21^{d}	380.9±4.03^{e}
Trolox/100 g)	CBC	269.9±0.21^{a}	297.4±9.76^{c}	142.3±6.36^{a}	495.8±23.69^{g}
AA, ABTS	OBC	314.3±5.59^{b}	386.5±34.44^{d}	424.8±1.84^{e}	376.2±0.35^{d}
(µmol Trolox/100 g)	CBC	309.8±13.86^{b}	247.8±0.42^{b}	193.6±3.04^{a}	601.0±16.69^{f}
Drying Time (min)	OBC	-	170.0±0.0^{a}	128.0±0.0^{b}	112.0±0.0^{c}
	CBC	-	170.0±0.0^{a}	135.0±0.0^{b}	113.0±0.0^{c}

(OBC: Organic; CBC: Conventional; GAE: Gallic Acid Equivalent). Different letters on the same two rows for each parameter indicate that the difference between the means is significant (p<0.05).

3.2. Effect of drying methods on total phenolic and antioxidants

Phenolic compounds are natural antioxidants that have the ability to reduce and eliminate negative properties of free radicals (Sonmezdag, 2015) also total phenolic compounds are secondary metabolites responsible for the colour, taste and aroma properties of fruits and vegetables (Meral, 2016).

Total phenolics content of fresh OBC and CBC samples were calculated as 903 and 866 mg/100g, respectively. The total phenolic content of OBC and CBC samples dried by applying 150, 300 and 450 W power with IMW

were 1246, 1076, 1752 and 732, 1205, 1346 mg/100g GAE, respectively (*Table 1*). Applied all drying power levels caused an increase in total phenolic content compared to fresh samples. According to the DPPH method, the antioxidant activity values of OBC and CBC samples dried at 150, 300 and 450 W were calculated as 646, 462, 665 and 287, 406, 796 μmol Trolox/100 g, respectively (*Table 1*). Power of 450 W drying resulted in the highest antioxidant activity for both product types.

The total phenolic content of OBC and CBC samples dried at 60, 70 and 80°C with HA was found to be 878, 1028, 1112 and 518, 699, 933 mg/100g GAE, respectively (*Table 2).* The antioxidant activity values of fresh OBC and CBC samples for DPPH were calculated as 427 and 270 μmol Trolox/100 g (*Table 2*). In DPPH and ABTS methods, the highest antioxidant capacity values were determined for OBC samples. According to the results of this study, it can be said that 80°C drying temperature is suitable for obtaining high total phenolic compound and antioxidants.

The total phenolic values obtained from the samples dried at 80°C and 150 W power level are close to each other. It can be said that the reason for this may be related to the fact that the drying times are close to each other (for OBC and CBC, respectively 80°C: 112-113 min; 150 W: 103-100 min). It can be said that the drying time decreased with the applied high drying temperature (80°C) and power (450 W), and accordingly, the final product color brightness (L*) and color difference (ΔE) values, total phenolic and total antioxidant values increased compared to fresh.

During product processing such as heat treatments, antioxidants naturally found in food may be destroyed and new components with antioxidant activity may be formed (Meral, 2016). The IMW power levels applied during drying increased the total antioxidant value of the product compared to the fresh ones according to DPPH method. Similarly, Choi et al. (2006) reported that there may be an increase in the amount of phenolic compounds compared to fresh ones due to the release of phenolic compounds after heat treatments. Calligaris et al. (2004) stated that the level and time of the applied heat procedure can change the antioxidant properties. Turkmen et al. (2005) reported that heat treatments caused a significant increase in the antioxidant activity of broccoli, peppers, green beans and spinach. Contrary to results of this study, Polat et al. (2022) investigated the effects of drying methods on the phenolic and volatiles of black carrot pomace and reported that drying reduces the amount of colorless phenolic. Guilherme et al. (2020) was determined that fresh conventional pepper samples had higher phenolic-antioxidant levels compared to organic samples.

3.3. Evaluating of drying kinetics

The time-dependent moisture content of OBC and CBC samples dried by using IMW and HA method are given in *Figure 2*. Increasing with the applied power and temperature significantly decreased the drying time ($p<0.05$). Although there is no distinctive difference in terms of drying OBC and CBC due to may be the material type is the same, it is seen that the drying methods and the applied power/temperature levels make a significant difference. Increasing with applied temperature and power levels, the product types demonstrated the same drying resistance to the same drying methods.

Drying rate tends to be stable in the early stages of the drying process both IMW and HA methods (*Figure 3*). The drying process for both OBC and CBC samples occurred mainly in the period of decreasing rate after a short warm-up period for HA.

The research findings were compared with the literature studies examining the differences between organic and conventional samples. Similarly, Arslan et al. (2020b) in a similar study compared the IMW drying kinetics of organic and conventional pepper, supports this result. Although the IMW and HA drying methods do not reveal a distinctive difference for the product types, it is clearly seen that the methods affect the way moisture is removed from the products. With lasted long time drying, heat and power are applied to the products for a longer time and this may also lead to the development of some undesirable features (Soysal et al., 2006). It can be said that the use of IMW and 300 and 450 W power levels for drying OBC and CBC samples were more economical in terms of lasted drying time.

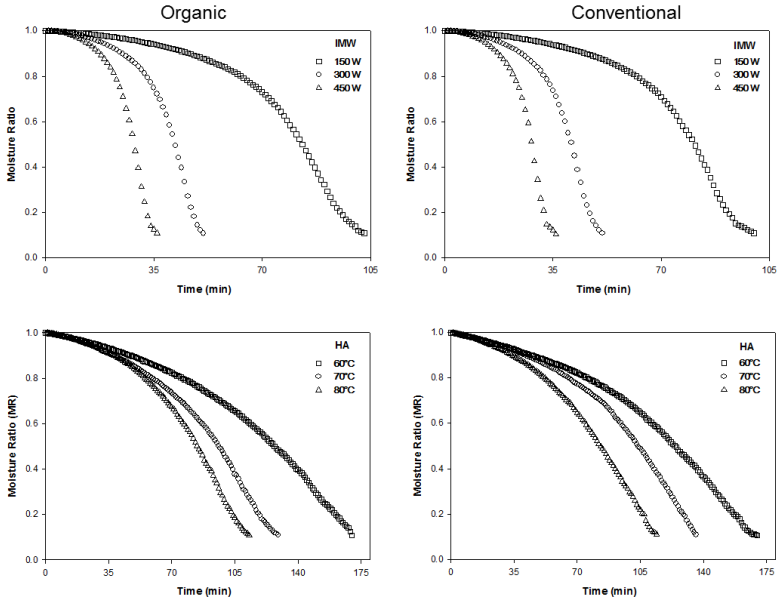

Figure 2. Moisture ratio change as a function of drying power/temperature of samples dried with intermittent microwave (IMWD) and hot air (HAD) drying

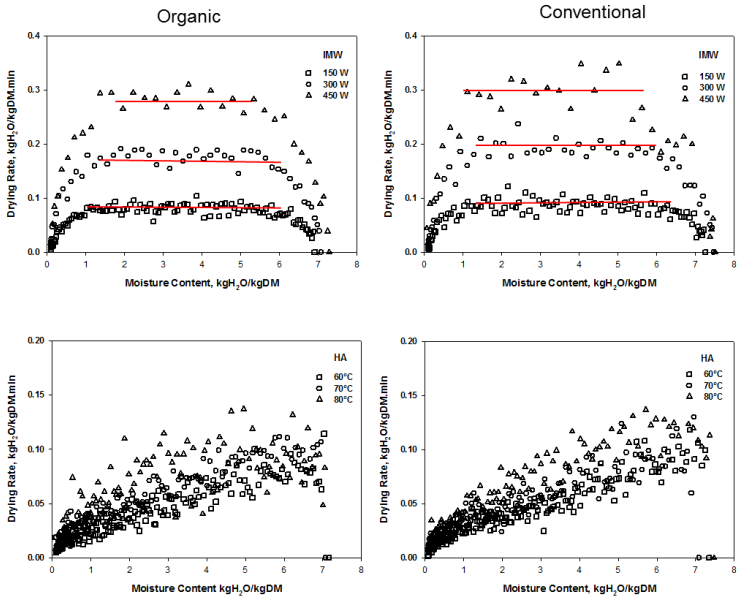

Figure 3. Variation of drying rate as a function of moisture content of dried samples by using intermittent microwave (IMW) and hot air (HA)

3.4. Modeling of drying curves

During the IMW and HA methods, the experimental moisture contents on the basis of dry weight were converted into humidity ratio (MR) values at different times and fitted against the drying time. In the study, the formulas and details of the models employed for drying kinetics were presented by Arslan et al. (2020a). For dried samples by IMW, the best fitting model for both OBC and CBC samples was the Logistic model (Model 7) with the values for the R^2 greater than 0.9918, the SEE of lower than 0.0255 and the RSS of lower than 0.0639 (Table 3). But, Verma model, it can be said that more accurate predictions can be made for OBC samples dried at 150 and 300 W compared to the Logistic model. For dried samples by HA, the best fitting model for both OBC and CBC samples was the Verma model (Model 9) with the values for the R^2 greater than 0.9975, the SEE of lower than 0.0142 and the RSS of lower than 0.0223 (*Table 3*).

Table 3. Fitting ability of eleven drying models for the intermittent microwave and hot air drying of organic and conventional samples

Product	Model No	IMWD at 150 W			IMWD at 300 W			IMWD at 450 W			HAD at 60°C			HAD at 70°C			HAD at 80°C		
		R^2	SEE	RSS	R^2	SEE	RSS	R^2	SEE	RSS	R^2	SEE	RSS	R^2	SEE	RSS	R^2	SEE	RSS
OBC	1	0.6230	0.1631	29.439	0.6056	0.1736	15.067	0.6153	0.1849	11.961	0.7887	0.1192	24.145	0.7633	0.1328	22.579	0.7410	0.1422	22.641
	2	0.9447	0.0650	0.4316	0.9868	0.0320	0.0503	0.9704	0.0521	0.0922	0.9845	0.0324	0.1776	0.9836	0.0351	0.0012	0.9891	0.0293	0.0954
	3	0.7139	0.1480	22.345	0.6971	0.1537	11.570	0.7064	0.1639	0.9129	0.8521	0.1000	16.898	0.8303	0.1129	0.0127	0.8164	0.1203	16.057
	4	0.8165	0.1191	14.326	0.7981	0.1267	0.7711	0.8176	0.1311	0.5672	0.9392	0.0643	0.6951	0.9251	0.0753	0.7146	0.9157	0.0819	0.7374
	5	0.9057	0.0947	0.4214	0.8897	0.1709	13.727	0.9043	0.0964	0.2976	0.9788	0.0380	0.2417	0.9723	0.0460	0.2645	0.9698	0.0492	0.2638
	6	0.9418	0.0667	0.4544	0.9757	0.0435	0.0928	0.9820	0.0406	0.0561	0.9985	0.0100	0.0170	0.9970	0.0150	0.0286	0.9974	0.0144	0.0230
	7	0.9926	0.0239	0.0577	0.9918	0.0255	0.0313	0.9954	0.0208	0.0142	0.9932	0.0215	0.0775	0.9927	0.0235	0.0699	0.9951	0.0198	0.0430
	8	0.8684	0.1014	10.276	0.8576	0.1076	0.5439	0.9888	0.033	0.0349	0.9501	0.0584	0.5704	0.9376	0.0690	0.5952	0.9351	0.0721	0.5672
	9	0.9930	0.0232	0.0545	0.9932	0.0233	0.0261	0.9885	0.0329	0.0358	0.9997	0.0045	0.0033	0.9982	0.0117	0.0174	0.9975	0.0142	0.0223
	10	0.8424	0.1098	12.305	0.9017	0.0110	0.0059	0.9774	0.0454	0.0702	0.8814	0.0896	13.555	0.9960	0.0174	0.0385	0.9926	0.0241	0.0645
	11	0.8542	0.1062	11.382	0.8443	0.1113	0.5948	0.8557	0.1166	0.4486	0.9429	0.0623	0.6522	0.8666	0.1005	12.719	0.7410	0.1435	22.642
CBC	1	0.6127	0.1734	30.076	0.6075	0.1800	16.193	0.6124	0.1919	12.889	0.7771	0.1276	27.669	0.7605	0.1273	21.874	0.7786	0.1287	18.724
	2	0.9794	0.0402	0.1603	0.9861	0.0342	0.0572	0.9914	0.0290	0.0287	0.9829	0.0355	0.2128	0.9822	0.0348	0.1626	0.9900	0.0275	0.0849
	3	0.7037	0.1524	23.006	0.6997	0.1590	12.390	0.7026	0.1705	0.9889	0.8395	0.1086	19.923	0.8276	0.1084	15.743	0.8473	0.1074	12.918
	4	0.8067	0.1238	15.011	0.8066	0.1289	0.7977	0.8179	0.1355	0.6057	0.9341	0.0698	0.8187	0.9189	0.0746	0.7404	0.9408	0.0671	0.5003
	5	0.9003	0.0893	0.7739	0.8967	0.0952	0.4263	0.9034	0.1002	0.3214	0.9760	0.0423	0.2982	0.9677	0.0472	0.2945	0.9814	0.0378	0.1573
	6	0.9755	0.0439	0.1904	0.9780	0.0430	0.0906	0.9778	0.0466	0.0738	0.9977	0.0130	0.0286	0.9964	0.0158	0.0333	0.9993	0.0070	0.0055
	7	0.9918	0.0255	0.0639	0.9943	0.0222	0.0237	0.9949	0.0226	0.0169	0.9932	0.0224	0.0845	0.9810	0.0361	0.1734	0.9958	0.0180	0.0359
	8	0.9878	0.0313	0.0951	0.9901	0.0295	0.0409	0.9816	0.0437	0.0610	0.9418	0.0658	0.7223	0.9364	0.0664	0.5813	0.9519	0.0608	0.4069
	9	0.9910	0.0267	0.0701	0.9897	0.0298	0.0427	0.9814	0.0432	0.0617	0.9989	0.0088	0.013	0.9994	0.0064	0.0055	0.9985	0.0106	0.0124
	10	0.7008	0.1532	23.236	0.9820	0.0389	0.0742	0.9678	0.0561	0.1071	0.9973	0.0141	0.0334	0.9983	0.0107	0.0154	0.9950	0.0194	0.0423
	11	0.8456	0.1106	11.989	0.8472	0.1146	0.6302	0.8513	0.1224	0.4944	0.8807	0.0939	14.806	0.9278	0.0704	0.6597	0.8816	0.0950	10.015

(OBC: Organic; CBC: Conventional; HAD: Hot Air Drying; IMWD: Intermittent Microwave Drying.) (Arslan et al. (2020a) provided the model numbers and names as follows; 1: Newton; 2: Page; 3: Henderson and Pabis; 4: Logarithmic; 5: Midilli; 6: Wang and Singh; 7: Logistic; 8: Two term; 9: Verma; 10: Two term exponential; 11: Diffusion approximation)

Information on the model constant values obtained is given in *Table 4* for IMW and HA drying methods. The drying coefficient (k) increased with increasing with at applied IMW power and HA temperatures.

Table 4. Logistic and Verma model constants of samples dried by intermittent microwave and hot air

Product	Drying Power (W)	Logistic Model Constant – Intermittent Microwave			Drying Temperature (°C)	Verma Model Constant – Hot Air		
		k	***a***	***b***		***k***	***a***	***b***
OBC	150	0.0882	0.0007	0.9678	60	-0.0022	17.282	-0.0070
CBC		0.0949	0.0005	0.9664		-0.0023	17.304	-0.0072
OBC	300	0.1883	0.0005	0.9705	70	-0.0025	14.592	-0.0113
CBC		0.1919	0.0005	0.9724		-0.0030	12.458	-0.0130
OBC	450	0.2705	0.0006	0.9763	80	-0.0055	24.881	-0.0100
CBC		0.2852	0.0005	0.9743		-0.0038	18.856	-0.0102

(OBC: Organic; CBC: Conventional)

3.5. Effective moisture diffusivity and activation energy

The effective moisture diffusivity (D_{eff}) and activation energy (E_a) values for the OBC and CBC samples dried with three different IMW powers and HA temperatures were given in *Table 5*. D_{eff} values of OBC and CBC samples dried by IMW were calculated as ranged from 4.29×10^{-9} to 13.39×10^{-9} $m^2 s^{-1}$ and 4.50×10^{-9} to 14.8×10^{-9}

m^2s^{-1} respectively. No statistically significant difference was observed between the D_{eff} values of OBC and CBC dried by IMW except for 450 W. D_{eff} values of OBC and CBC samples dried by HA were found to vary between $2.59x10^{-9}$ to $4.36x10^{-9}$ m^2s^{-1} and $2.82x10^{-9}$ to $4.24x10^{-9}$ m^2s^{-1}, respectively, depending on the applied temperature level. Difference between the D_{eff} values of OBC and CBC dried by applying 60 and 80°C temperature levels was not statistically significant, but the difference was significant for the samples dried by applying 70°C.

Table 5. Effective moisture diffusivity (D_{eff}) coefficients, Activation Energy (E_a) values of samples

Product	Drying Power (W)	Intermittent Microwave			Drying Temperature (°C)	Hot Air		
		D_{eff} ($x10^{-9}$ m^2s^{-1})	D_0 ($x10^{-8}$ m^2s^{-1})	E_a ($x10^{-3}$ Wg^{-1})		D_{eff} ($x10^{-9}$ m^2s^{-1})	D_0 ($x10^{-6}$ m^2s^{-1})	E_a (kJ mol^{-1})
OBC	150	4.29±0.43[a]	2.24	8.41	60	2.59±0.23[a]	3.31	25.5
CBC		4.50±0.20[a]				2.82±0.13[a]		
OBC	300	8.62±0.22[b]			70	3.76±0.35[c]		
CBC		9.20±0.43[b]				3.22±0.23[b]		
OBC	450	13.39±0.57[c]	2.40	8.40	80	4.36±0.37[d]	3.41	19.72
CBC		14.80±0.95[d]				4.24±0.42[d]		

Different letters in the same column indicate that the difference between the means is significant (p<0.05). (OBC: Organic; CBC: Conventional)

The samples dried with IMW have higher D_{eff}, lower the pre-exponential factor of the Arrhenius equation (D_0) and E_a values. High MW powers accelerate the water molecules and evaporate faster by increasing the vapor pressure in the product, thus providing a faster reduction in moisture content corresponding to higher D_{eff} values (Thuwapanichayanan, et al., 2011; Darvishi, et al., 2013; Soysal et al., 2009). The D_{eff} values determined were different from 10^{-11} to 10^{-9} m^2s^{-1} compared to the black carrot materials used in other studies (Haq et al., 2018; Talih et al., 2017). The D_{eff} values of the samples dried at 80°C and 150 W are close to each other (for OBC and CBC, respectively 80°C:4.36 and 4.24 m^2s^{-1}; 150 W: 4.29 and 4.50 m^2s^{-1}).

The E_a values determine the sensitivity of the diffusivity to temperature. Higher E_a also indicates that the reaction rate is more sensitive to changes in temperature (Turhan et al., 1997; Ma et al., 2017). Low E_a values produce a fast reaction, while high E_a values produce a slow reaction (Ma et al., 2017). The E_a values obtained from the slope of the lines as a result of the comparison of the $\ln(D_{eff})$ value and the m/P_a value for IMW were calculated as $8.41x10^{-3}$ and $8.40x10^{-3}$ W g^{-1} for OBC and CBC samples, respectively. This result shows that the growing conditions of OBC or CBC dried by IMW did not significantly change the structural properties. OBC and CBC samples demonstrated the same resistance to moisture carried over from the drying material as a result of IMW. There are similar studies on the lack of a significant difference in E_a values for organic and conventional samples obtained in the current study (Arslan et al., 2020b).

The E_a values of OBC and CBC samples dried by HA were found as 25.50 and 19.72 kJ mol^{-1}, respectively. The E_a values for OBC and CBC samples dried by HA have a significant difference. Growing conditions of OBC and CBC samples dried with HA significantly was affected the structural properties.

The rate of a chemical reaction generally increases with increasing temperature values (Ma et al., 2017). As the reaction temperature increases, collisions become more frequent as a result of the increase in the average molecular kinetic energy and the increase in the number of molecules with kinetic energy exceeding the E_a (Ma et al., 2017). The E_a values obtained for the samples dried with the IMW were resulted lower values than the HA. This may cause of removing moisture from the product as a result of the working principle of the drying methods.

4. Conclusions

This study was carried out to organic and same variety of conventional black carrots dried by using IMW and HA method and to evaluate the effects of applied power and temperature levels on color and quality properties and to model the drying kinetics data mathematically. The samples dried with IMW had higher D_{eff} (4.29-$14.80x10^{-9}$$m^2s^{-1}$) and values compared to HA (2.59-$4.24x10^{-9}$ m^2s^{-1}). L* and ΔE values of the final products increased significantly by increasing the power/temperature levels applied during drying and the powder samples were lighter in color compared to the fresh samples.

The total phenolic (OBC: 903.3 mg/100g GAE; CBC: 865.8 mg/100g GAE) and total antioxidant capacity (OBC: 427.4 μmol Trolox/100 g; CBC: 269.9 μmol Trolox/100 g according to DPPH method) values were higher in fresh OBC samples compared to the conventional variety. These results demonstrated that OBC is superior to the CBC in terms of higher total phenolic and total antioxidant content. The total phenolic components, which are sensitive to heat, were not decrease or increase in parallel with the temperature/power levels applied with the drying methods so it can say that the phenolic components are affected differently depending on the product type, the food structure and composition. As a result, it was determined that the temperature/power levels applied to the products during the drying process, thus the drying times and the methods of removing moisture from the product are effective in the preservation of the total phenolic components. For this reason, it is important to use appropriate temperature and power levels for the protection, increase and sustainability of phenolic compounds in terms of nutritiveness of the products. The total phenolic and total antioxidant capacity values were better preserved with the IMW method, which requires low E_a. Evaluation of other organic samples in terms of drying parameters compared to conventional will shed light on future studies.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Türkiye Ekonomisinde Tarımsal Enerji Tüketimi-Ekonomik Büyüme İlişkisi: Bir Saklı Eşbütünleşme Analizi

Agricultural Energy Consumption-Economic Growth Relationship in Turkish Economy: A Hidden Cointegration Analysis

Murat ÇETİN[1], Servet KAPÇAK[2*], Aycan CAN[3]

Öz

Enerji ekonomistlerine göre ekonomik büyüme ve kalkınmanın temelinde enerji faktörü yatmaktadır. Bu yaklaşımda enerji tüm mal ve hizmetlerin üretimi sürecinde olmazsa olmaz bir üretim faktörü olarak kabul edilmektedir. Ayrıca kalkınmanın başlangıcında tarımsal faaliyetlerin ön planda olduğu, tarımdan sanayiye sanayi sektöründen de hizmet sektörüne doğru bir yapısal dönüşümün gerçekleştiği bilinmektedir. Bununla birlikte gerek son yıllarda dünya ekonomisinde yaşanan gelişmeler gerekse tarım sektörünün ülkede kilit fonksiyonlar görmesi nedeniyle pek çok ülke bu sektörün gelişimine özel bir önem atfetmektedir. Tarım sektörünün gelişim göstermesi bu sektör tarafından kullanılan enerji miktarının da artırılması ihtiyacını gündeme getirmektedir. Enerji maliyetlerinin günden güne artış göstermesi tarım sektörünü zora sokmakla birlikte artan enerji tüketiminin ülkenin ekonomik büyümesini nasıl etkileyeceği bir araştırma konusu olarak ortaya çıkmaktadır. Enerji tüketimi-ekonomik büyüme ilişkisini araştıran literatür bu konuyu sektörel bazda nadiren ele almaktadır. Bu bağlamda; tarım sektöründeki enerji tüketiminin ekonomik büyümeyi etkileyip etkileyemeyeceği önem arz etmektedir. Bu çalışma tarımsal enerji tüketimi-ekonomik büyüme ilişkisini Türkiye ekonomisi için 1990-2018 döneminde araştırmayı amaçlar. Değişkenlerin durağanlık analizi için kullanılan ADF ve PP birim kök testi sonuçları değişkenlerin birinci farkında durağan hale geldiğini ortaya koymaktadır. Değişkenler arasındaki uzun dönem ilişkisi yeni nesil testlerden biri olan Hatemi J-Irandoust saklı eşbütünleşme testi kullanılarak araştırılmaktadır. Değişkenlerin katsayıları ve nedensellik ilişkisi sırasıyla FMOLS tekniği ve saklı hata düzeltme modeli ile incelenmektedir. Bulgular tarımsal enerji tüketimi + bileşeni ile ekonomik büyüme + bileşeni arasında bir eşbütünleşmenin varlığını göstermektedir. Bulgular aynı zamanda tarımsal enerji tüketimi + bileşeni ile ekonomik büyüme + bileşeni arasında pozitif bir ilişkinin varlığını işaret etmektedir. Son olarak ekonomik büyüme + bileşeninden tarımsal enerji tüketimi + bileşenine doğru işleyen tek yönlü bir nedensellik söz konusudur. Bu sonuçlar, Türkiye'nin ekonomik büyümesinde tarımsal enerji tüketiminin etki sahibi olduğunu göstermektedir. Çalışma, Türkiye ekonomisinin büyümesi için tarım sektörü ile ilişkili bazı politika tavsiyeleri sunabilmektedir.

Anahtar Kelimeler: Türkiye, Tarımsal enerji tüketimi, Ekonomik büyüme, Saklı eşbütünleşme, Saklı hata düzeltme modeli

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Abstract

According to energy economists, the energy factor underlies economic growth and development. In this approach, energy is accepted as an indispensable production factor in the production of all goods and services. In addition, it is known that agricultural activities are at the forefront at the beginning of development, and a structural transformation has taken place from agriculture to industry and from the industrial sector to the service sector. However, due to the developments in the world economy in recent years and the fact that the agricultural sector plays a key role in the country, many countries attach special importance to the development of this sector. The development of the agricultural sector brings the need to increase the amount of energy used by this sector. The increase in energy costs day by day puts the agriculture sector in a difficult situation, and how the increasing energy consumption will affect the economic growth of the country emerges as a research topic. The literature investigating the relationship between energy consumption and economic growth rarely addresses this issue on a sectoral basis. In this context; It is important whether energy consumption in the agricultural sector can affect economic growth. This study aims to investigate the relationship between agricultural energy consumption and economic growth for the Turkish economy in the period of 1990-2018. The results of the ADF and PP unit root tests used for the stationarity analysis of the variables reveal that the variables become stationary at the first difference. The long-term relationship between the variables is investigated using the Hatemi J-Irandoust hidden cointegration test, which is one of the new generation tests. The coefficients of the variables and the causality relationship are examined with the FMOLS technique and the hidden error correction model, respectively. The findings show the existence of a cointegration between the + component of agricultural energy consumption and the + component of economic growth. The findings also indicate the existence of a positive relationship between the + component of agricultural energy consumption and the + component of economic growth. Finally, there is a unidirectional causality running from the + component of economic growth to + component of agricultural energy consumption. These results show that agricultural energy consumption has an impact on Turkey's economic growth. The study can offer some policy recommendations related to the agricultural sector for the growth of the Turkish economy.

Keywords: Agricaltural energy consumption, Economic growth, Hidden cointegration, Hidden error correction model

1. Giriş

Enerji, ilkel çağlardan beri tüm canlıların kullandığı önemli bir faktör olmuştur. Üretim ve tüketim faaliyetlerinde temel girdi olarak kabul edilmektedir. Modern ekonominin başlangıcı kabul edilen Adam Smith'den günümüze kadar klasik iktisatçılar başta olmak üzere ana akım iktisatçılarının büyük bir kısmı, büyüme ve kalkınmanın temel girdisi olarak fiziksel sermaye, emek ve doğal kaynaklar üzerinde durmuşlardır. Ancak 19. yüzyılda küreselleşmenin de etkisiyle sanayileşmiş ülkeler enerjinin iktisadi büyümenin temel girdilerinden biri olduğunu fark etmişlerdir. Sanayi devrimiyle enerji ihtiyacı artış göstermiştir. Ayrıca Birinci Dünya Savaşı'yla devam etmesi ve diğer taraftan 1973 ve 1979 yıllarında meydana gelen enerji darboğazı, enerjinin ekonomideki yerinin fark edilmesinde etkili olmuştur (Bayraç, 2010). Enerjinin ekonomideki yerinin fark edilmesiyle birlikte ekonomi için birinci güç olarak kabul görmektedir. Enerji sadece ekonomik büyümeyle değil aynı zamanda emek, fiziki sermaye, sürdürülebilir teknoloji ve kaynaklarla önemli ilişki içerisindedir (Rahman ve Bashir, 2015). Enerji, ekonomik faaliyetlerin gerçekleştirilmesinde, insan refahının artışında hayati bir öneme sahiptir ve sürdürülebilir bir üretimin gerçekleşmesinde itici güç olarak piyasada yerini almıştır (Faridi ve Murtaza, 2013).

Tarım sektörü, diğer sektörler kadar ülkenin gelişiminde ve insan ihtiyaçlarını karşılamada çok önemli bir paya sahiptir. Nüfusun gıda ihtiyacını karşılaması ve endüstriyel üretime girdi temin etmesi bakımından stratejik bir öneme sahip olduğu için ekonomi politikalarında önemli bir konum üstlenmektedir. Tarım toplumu döneminde geçimlik ihtiyaçların karşılanması amacıyla gerçekleştirilen tarımsal faaliyetler sanayi devrimi sonrasında artan kentleşme eğilimine bağlı olarak aynı zamanda ticari bir sektör haline gelerek gelişimini devam ettirmiştir. Böylece uluslararası ve ulusal olarak meydana gelen ticaretin yaygınlaşması ve teknolojik ilerlemeler sonucunda ortaya çıkan makineleşme süreci, küresel bazda üretim sürecini etkilemiş ve hızlandırmıştır. Bu hızlı gelişimden dolayı tarım sektörü önemli derecede payını almıştır (Akyol, 2020). Ancak dünya nüfusunun sürekli artış göstermesi tarıma elverişli alanların çeşitli nedenlerle azalması, özellikle gelişmekte olan ve geri kalmış ülkelerde yetersiz beslenme ve açlık sorununa neden olmaktadır (Kuca ve Yağdı, 2021).

Diğer sektörlerde olduğu gibi tarımsal üretimin artmasında da enerji kullanımı en az makineleşme kadar önemli bir paya sahiptir (Moghaddasi ve Pour, 2016). Teknolojinin hızla ilerlemesi ve kullanımının yaygınlaşması tarım sektöründe de olumlu sonuçlar vermektedir (Yegül ve ark., 2019). Enerji kullanımı ile birlikte üretim standartları yükselirken; verimlilik düzeyi, tarımsal nüfus ve sulanabilir alanların arttığı, sürdürülebilir tarımsal faaliyetlerin de hız kazandığı görülmektedir. Tarımsal üretimde enerji kullanımının belirtilen olumlu etkileri yanında; kimyasal gübre ve zirai ilaç yapımı ile makineleşmeden ötürü artan enerji tüketimi, çevre ve insan sağlığını tehdit etmeye başlamıştır (Fadavi ve ark., 2011). Geleneksel üretim süreçlerinden modern tarıma geçilmesi ticari enerji kullanımını hızlı şekilde arttırmıştır. Bu kontrolsüz artış beraberinde tarımsal üretimde kullanılan enerjinin etkinliğinin azalmasını getirmiştir (Alipour ve ark., 2012). Modern tarım uygulamaları başlaması ile mal ve hizmet hacmindeki artışlar enerjiye olan ihtiyacı artırmış ve enerjinin uluslararası düzeyde en önemli faktörlerden biri olmasına ortam hazırlamıştır (Moghaddasi ve Pour, 2016).

Tarımda enerjinin etkin ve verimli kullanımı parasal kaynakların daha fazla tasarruf edilmesinin yanında, fosil yakıt rezervlerinin korunmasına ve çevre kirliliğinin azaltılmasına katkı sağlayacağı gibi, sürdürülebilir tarımın da temel şartları ve unsurlarından birini oluşturmaktadır (Mohammedi ve ark., 2008). Diğer yandan tarımsal enerji kullanımında etkinliğin arttırılmasında girdi miktarının azaltılarak gelirde göreceli olarak artış sağlamak veya çıktı düzeyini arttırmak üreticiler ve ülkeler açısından öneme sahiptir (Shrestha, 2002). Ayrıca tarımsal üretimde enerji maliyetleri de üretkenlik açısından olumlu ya da olumsuz etkilere sahiptir. Ucuz enerjiye kolay ulaşabilen ülkeler üretim ve girdi maliyetlerini bu anlamda düşürürken enerjiyi daha pahalı elde eden ülkeler ise yüksek üretim maliyetleri dolayısıyla zamanla piyasada rekabet gücünü kaybederek ülke ekonomisine büyük maliyetler getirmektedirler (Akyol, 2020). Bu sebeple yenilenemeyen enerji kaynakları yerine ekonomide rüzgar, su ve güneş enerjisi kaynaklarından istifade edilmelidir (Çetin ve ark., 2020).

Çalışmada Türkiye ekonomisi analiz edilmiştir (*Tablo 1.*) Türkiye ekonomisinde 1990-2018 dönemine ilişkin tarımsal enerji tüketimi ve ülkenin ekonomik büyümesini temsilen kişi başına gelir rakamlarını sergiler. 1990 yılında tarımsal enerji kullanımı 82 terajoule iken 1995'te 111 terajoule, 2000'de 122 terajoule, 2010'da 206 terajoule, 2018'de 183 terajoule olarak gerçekleşmiştir. 1990-2018 döneminde bazı yıllarda dalgalanma görülmekle birlikte genelde bir artış trendi kendisini hissettirmektedir. Ekonomik büyüme ölçütü olarak ele alınan kişi başına reel GSYİH değeri 1990'da 5354 ABD doları iken, 1995'te 5782 ABD doları, 2000'de 6543 ABD

doları, 2010'da 8491 ABD doları ve 2018'de ise 12006 ABD doları olarak hesaplanmıştır. Kişi başına reel GSYİH değerlerinin de söz konusu dönemde bir artış eğilimi sergilediği görülmektedir. Türkiye ekonomisine ilişkin bu iki göstergenin 1990-2018 döneminde genelde bir artış trendi yaşaması her iki serinin birbirini etkileyebileceği sorusunu gündeme getirmekte ve iki değişken arasında bir ampirik araştırmanın yapılabileceğini ortaya koymaktadır.

Tablo 1. Tarım sektörü enerji tüketimi ve kişi başına GSYİH verileri

Table 1. Agricultural energy consumption and per capita GDP data

Yıllar	Tarımsal enerji tüketimi (Terajoule)	Kişi başına reel GSYİH (2015 US dollar)
1990	82	5354
1995	111	5782
2000	122	6543
2001	122	6075
2002	133	6373
2003	122	6644
2004	135	7194
2005	138	7738
2006	147	8173
2007	162	8483
2008	210	8451
2009	197	7942
2010	206	8491
2011	223	9299
2012	185	9586
2013	177	10225
2014	184	10549
2015	156	11006
2016	152	11187
2017	172	11835
2018	183	12006

Kaynak: International Energy Agency (https://www.iea.org/data-and-statistics); World Bank World Development Indicators (https://databank.worldbank.org).

Yukarıdaki değerlendirmeler ışığında; çalışmanın temel amacı, tarımsal enerji tüketiminin ekonomik büyümeye nasıl bir etkide bulunacağını Türkiye için 1980-2018 dönemi verilerini kullanarak araştırmaktır. Mevcut literatürde enerji tüketimi ve ekonomik büyüme ilişkisini analiz eden pek çok çalışma olmakla birlikte tarımsal enerji tüketimi ve ekonomik büyüme ile ilgili çalışmalar oldukça sınırlıdır. Bu yönüyle söz konusu literatüre önemli bir katkı sunabilecektir. Diğer taraftan enerji tüketimi-ekonomik büyüme ilişkisi üzerine yoğunlaşan ampirik çalışmaların bir diğer özelliği genelde simetrik ilişkileri araştırmasıdır. Oysaki çalışmamızda tarımsal enerji tüketimi ile ekonomik büyüme arasındaki asimetrik ilişkiler yani her iki serinin + ve – bileşenleri arasındaki uzun dönem ve nedensel ilişkiler analiz edilmektedir. Bu amaçlar doğrultusunda değişkenler arasında bir uzun dönem ilişkisinin olup olmadığı Hatemi-J ve Irandoust, (2012) saklı eşbütünleşme testi ile araştırılmaktadır. Ayrıca değişkenler arasındaki nedensellik ilişkisi Granger ve Yoon, (2002) saklı hata düzeltme modeli ile analiz edilmektedir. Ampirik sonuçlar değişkenler arasındaki asimetrik ilişkileri içerdiğinden çalışma gelecekteki çalışmalara ve politika yapıcılarına önemli önerilerde bulunabilecektir.

Çalışmanın bundan sonraki kısımları şu şekilde dizayn edilmiştir: İkinci kısımda ampirik literatüre yer verilmiştir. Çalışmanın üçüncü kısmında Türkiye ekonomisinde tarımsal enerji tüketimi ve ekonomik büyüme arasındaki ilişkiyi incelemek için ampirik model kurulmuş ve veri seti ele alınmıştır. Dördüncü kısım metodoloji üzerinde durur. Beşinci kısımda elde edilen ampirik sonuçlar tablolaştırılmakta ve yorumlanmaktadır. Çalışmanın son bölümü olan sonuç kısmında ise genel bir değerlendirme yapılarak elde edilen sonuçlar ve bu sonuçlara göre uygun politika önerileri sunulmaktadır.

2. Ampirik Literatür

Ampirik çalışmalar incelendiğinde bir grup literatürün enerji tüketimi-ekonomik büyüme ilişkisi üzerinde durduğu bazı çalışmaların da tarımsal enerji tüketimi ile ekonomik büyüme arasındaki ilişkini araştırdıkları görülmektedir.

Kraft ve Kraft (1978), enerji tüketimi-ekonomik büyüme ilişkisi üzerinde duran ilk çalışmalardandır. Amerika Birleşik Devletleri ekonomisi için 1947-1974 dönemine ait zaman serisi verileri kullanılmaktadır. Bu çalışma söz konusu ilişkiyi Granger nedensellik testi ile analiz etmiş ve sonuç olarak ekonomik büyümeden enerji tüketimine doğru tek taraflı bir nedenselliğe işaret etmiştir. Dvoskın (1982), İsrail ekonomisini dikkate alarak yaptığı çalışmada İsrail tarımının büyük bir bölümün enerjiye bağlı olduğu sonucuna ulaşmıştır. Tarımın bu kadar gelişmiş olduğu ve İsrail tarımın %50 sinin kullandığı enerjiyi sadece su taşımak ve çiftliklere su sağlamak olduğu bunların tümünü elektrik enerjisiyle sağladığını tespit etmiştir. İsrail hükümeti yaşanan enerji kriziyle baş edebilmek için çeşitli enerji politikalarını geliştirme yoluna gitmiştir. Bundan dolayı çeşitli alternatif enerji olan ya da diğer ismi yenilenebilir enerji türlerinden faydalanmaya gitmiştir.

Karkacier ve ark. (2006), Türkiye'de enerji tüketimi ve tarımsal üretkenlik arasındaki ilişkiyi 1971- 2003 yılları arası dönemleri arasını ele alan bir çalışma yapmışlardır. Regresyon modeli sonuçları; enerji tüketimi ile tarımsal üretkenlik arasında yakın ve pozitif bir ilişki olduğunu göstermiştir. Söz konusu çalışmada ayrıca birim tarımsal alana uygulanacak yakıt faktörlerin tarımda enerji kullanımını arttırıcı etki oluşturacağını tespit etmişlerdir. Fuglie ve ark. (2007), tarımsal üretimde verimliliği analiz etmişlerdir. ABD ekonomisini baz alarak 1948-2014 yıllarına ait veriler kullanmışlardır. ABD de üretkenliğin tarımsal kalkınmanın itici gücü olduğu sonucuna varmışlardır. Ayrıca 1980 yılları sonrası periyotta sermaye, emek, kimyasallar, toprak ve enerji gibi tarımsal üretimin temel faktörlerinde azalma meydana gelmişse de üretkenlikte artış yaşandığını dile getirmiştir. Bu dönemde üretimde meydana gelen artışta tarımsal ürün fiyatlarındaki artış sınırlandırmıştır.

Adom (2011), Gana üzerine yaptığı çalışmasında enerji tüketimi ve ekonomik büyüme ilişkisini incelemiştir. 1971-2008 dönemine ait veriler ile değişkenlerin nedensellik bağlamında yönünü belirlemek için Granger nedensellik testi tercih edilmiştir. Yapılan ampirik analiz sonucuna göre; ekonomik büyümeden enerji tüketimine doğru tek taraflı bir nedensellik söz konusudur. Bu sonuç dikkate alınırsa, Gana ekonomisi üzerinde büyüme odaklı enerji hipotezi ya da koruma hipotezinin varlığı bulunmuştur. Sebri ve Abid (2012), tarım ekonomisinde enerjinin rolüne değinmişlerdir. Tunus ekonomisini dikkate alarak enerji tüketimi, tarım sektörü ve ekonomik büyüme gibi değişkenleri kullanarak aralarındaki ilişkiyi araştırmışlardır. Çalışmada 1980-2007 dönemine ait veriler kullanılmıştır. Kullanılan Granger nedensellik testine göre enerjinin bileşenleri arasında (petrol ve elektrik tüketimi) direk bir ilişkinin varlığı bulunmuştur. Ayrıca, ticari açıklık ve enerji tüketimi tarımsal katma değerin nedenidir. Böylece enerjiden büyümeye ve ticaretten büyümeye doğru Tunus tarım sektöründe bir nedensellik söz konusudur.

Jebli ve Youssef (2015), Tunus ekonomisini dikkate almışlardır. Metodolojik olarak Vektör hata düzeltme modeli ve Granger nedensellik testi, diğer taraftan da modelde kişi başı düzen karbondioksit emisyonu, ekonomik büyüme, yenilenebilir enerji ve yenilenemeyen enerji tüketimi, ticari açıklık ve tarımsal katma değer değişkenleri kullanılmıştır. 1980-2014 dönemine ait yıllık verileri kapsayan çalışma kısa dönemde kişi başına düşen karbondioksit emisyonu ve tarımsal katma değer arasında, ticaret ile tarımsal katma değer arasında tek taraflı, uzun dönemde ise yenilenebilir enerji ve yenilenemeyen enerji tüketimi ve tarımsal katma değer arasında anlamlı bir ilişki olduğu sonucuna varılmıştır. Moghaddasi ve Paur (2016), 1974-2012 dönemine ait yıllık verileri kullanarak Solow artığı çerçevesinde tarımsal üretim ile enerji tüketimi arasındaki ilişki incelemişlerdir. Cobb-Dauglas üretim fonksiyonu tahmininden elde edilen sonuçlar; emek, sermaye ve enerji değişkenlerinde meydana gelen %1'lik bir değişim tarımsal katma değerinde sırasıyla %4.07, %0.09 ve %0.49 bir değişime yol açmaktadır. Bu durum emek, sermaye ve enerjinin tarımsal katma değerin dolayısıyla tarımsal üretimin önemli belirleyicileri olduğunu kanıtlamaktadır.

Shahbaz ve ark. (2016), 1972-2011 döneminde Pakistan ekonomisini inceleyerek ekonomik büyüme, tarım ve modern sektör büyümesi, finansal gelişme ile enerji tüketimi arasındaki ilişkiyi analiz etmişlerdir. Çalışmada ARDL sınır testi ve Granger nedensellik tekniğinden istifade edilmiştir. Nedensellik testi sonucuna göre genel ekonomik büyüme enerji talebinin nedenidir. Diğer taraftan modern sektördeki büyüme ile enerji tüketimi, finansal gelişme ile enerji tüketimi arasında iki yönlü nedenselliğe rastlanmıştır. Ayrıca, enerji tüketimi tarımsal

büyümenin nedenidir. Mirza ve Kanwal (2017), 1971-2009 dönemine ait yıllık veriler ile ekonomik büyüme, enerji tüketimi ve karbon emisyonu arasındaki ilişkiyi bu değişkenleri modelleyerek Pakistan ekonomisi analiz etmişlerdir. İlk olarak bu değişkenler arasındaki eşbütünleşme varlığını tespit etmek için Johansen-Julius eşbütünleşme testi kullanılmıştır. Uzun vadeli ilişkinin varlığı için ARDL yaklaşımına başvurulmuştur. Yapılan eşbütünleşme ve nedensellik testi sonucuna göre; değişkenler arasında eşbütünleşmenin varlığı tespit edilmiş, değişkenler arasında çift taraflı bir nedensellik ilişkinin olduğu açıklanmıştır.

Chandio ve ark. (2019), 1984-2016 dönemini kapsayacak şekilde Pakistan ekonomisini araştırmışlardır. Bu çalışmada ARDL yaklaşımı kullanılmış, Pakistan tarım ekonomisi üzerinde değişkenlerin uzun dönem ve kısa dönem ilişkilerine bakılmıştır. Çalışmanın bulguları gösteriyor ki; uzun ve kısa dönemde tarımsal ekonomik büyüme, gaz ve elektrik tüketimi tarafından pozitif olarak etkilenmektedir. Uzun dönemde gaz ve elektrik tüketimi elastikiyet katsayıları sırasıyla 0.906 ve 0.421, kısa dönemde ise 0.590 ve 0.276 olarak tahmin edilmiştir. Tuna ve Tuna (2019), Asya'nın 5 ülkesi için söz konusu ilişkiyi 1980-2015 dönemine ait yıllık veriler kullanarak test etmişlerdir. Modele dahil edilen değişkenler arasındaki ilişkiyi araştırmak için Hacker ve Hatemi-J yöntemi kullanılmıştır. Elde edilen ampirik sonuçlara göre; genel olarak ekonomik büyüme ve yenilenebilir enerji tüketimi arasında herhangi bir nedensellik olmadığı belirlenmiştir.

Kahouli (2019), 1990-2015 dönemini kapsayan analizlerinde 34 OECD üyesi üzerinde durmuşlar, panel GMM tahmin tekniği yardımıyla iki değişken arasında çift yönlü nedenselliğin varlığına rastlamışlardır. Altiner (2019), 1971-2014 dönemi verileriyle Meksika, Endonezya, Nijerya ve Türkiye (MINT)'yi incelemiştir. Bir panel veri analizi niteliğinde olan bu çalışma enerji tüketimi ile ekonomik büyüme arasında bir nedenselliğe ulaşamamıştır. Raeeni ve ark. (2019), tarımsal enerji tüketimi ile ekonomik büyüme arasındaki ilişkiyi analiz eden çalışmalara bakıldığında, İran tarım sektörü üzerinde durmuştur. İran tarımı uzun yıllardır enerji faktörünü yoğun şekilde kullanmaktadır. Bundan dolayı büyüme ve ihracat bakımından önemli sonuçlar doğurabileceği belirtilmektedir. Bu çalışmada 1967-2015 dönemi dikkate alınarak, nedensellik ve eşbütünleşme analiz teknikleri kullanılmıştır. Çalışma enerji tüketiminden ekonomik büyümeye doğru tek taraflı bir nedensellik ortaya koymuştur. Diğer taraftan modele dâhil edilen ihracat unsuru ile enerji tüketimi arasında herhangi bir nedenselliğin varlığı tespit edilememiştir. Başka bir bulguya göre tarım alanında kullanılan enerji miktarının %1 oranında artması uzun dönemde tarımsal büyümeyi %1.29 oranında artırmaktadır.

Liu ve ark. (2019), düşük karbonlu tarımın gelişimi, sürdürülebilir tarımsal kalkınmada etkili bir yol olduğunu öne sürmüşlerdir. 2007- 2017 dönemine ait yıllık veriler kullanıldığı çalışmada Çin ekonomisi baz alınmıştır. Çin tarımında kullanılan düşük karbonlu tarımsal enerji tüketimi nüfus faktörünü etkilediği gibi yaşam standartlarını da etkilemektedir. Bu faktörlerin katkı oranlarını hesaplamak için LMDI indeks yöntemi kullanılmıştır. Elde edilen sonuçlara göre; hem teknolojik faktörler hem de düşük karbonlu teknolojik faktörler tarımsal karbon emisyonunu düşürebilmekte ve düşük karbonlu teknolojik faktörlerin tarımsal karbon emisyonunu düşürmede tarımsal teknolojik faktörlerden daha güçlü olduğu tespit edilmiştir. Diğer bir taraftan toplam nüfus karbon emisyonunu pozitif etkilemektedir ancak bu etki güçlü değildir.

Akyol (2020), tarımsal üretimde kullanılan enerji tüketimi ve tarımsal katma değer değişkenleri arasındaki ilişkiyi araştırmıştır. Modele dâhil edilen ülkeler AB'ye üye ve geçiş ekonomileri olan 10 ülkedir. Çalışmada 2019-2017 periyoduna ait yıllık veriler kullanılmış ve panel veri teknikleri ile ilişkiler test edilmiştir. Elde edilen ampirik bulgulara göre; tarımsal enerji tüketimi tarımsal katma değer üzerinde pozitif bir etkiye sahip olup, tarımsal enerji tüketiminin tarımsal büyümeyi artırdığı şeklinde yorumlanabilir. Fan ve Hao (2020), çalışmalarında Çin ekonomisi ele alınmıştır. Bu çalışmanın temel amacı, 2000-2015 yıllarına ait verileri ve ekonomik büyüme, yenilenebilir enerji tüketimi ve doğrudan yabancı yatırımları değişkenlerini kullanarak analiz etmişlerdir. Yapılan nedensellik analizi sonucuna göre yenilenebilir enerji tüketimden ekonomik büyümeye doğru tek yönlü bir ilişkinin olduğu dolayısıyla enerji öncülüğünde ekonomik büyüme hipotezinin varlığı ispatlanmıştır. 8 MENA ülkesi için bir panel veri çalışması gerçekleştiren Erdoğan ve ark. (2020), 1990-2014 döneminde enerji tüketiminin ekonomik büyümeye neden olduğu kanısına varmışlardır.

Yanıktepe ve ark. (2021), 1970-2015 döneminde Johansen eşbütünleşme tekniği ve Granger nedensellik testini uygulayarak bir zaman serisi analizi gerçekleştirmişlerdir. Çalışma enerji tüketimi ile büyüme arasında pozitif bir ilişkinin varlığına dair kanıtlar sunmuştur. Bu bulgu BRICS ve ASEAN ülkeleri için bir panel veri analizi yapan Rahman (2021)'ın bulgularıyla uyuşmaktadır. Sonuçlar aynı zamanda ilgili değişkenler arasında çift yönlü bir

nedenselliğe işaret etmiştir. Alpdoğan (2021), ekonomik büyüme ile enerji tüketimi arasındaki ilişkiyi ele aldığı çalışmada, 1970-2012 dönemine ait yıllık veriler kullanmıştır. Türkiye örneği araştırılarak elde edildiği bulgulara göre ekonomik büyüme ile enerji tüketimi arasında uzun dönemde bir ilişki söz konusudur.

Rokicki ve ark. (2021), Avrupa ülkelerinde tarımsal alanda kullanılan enerji tüketimini ve değişimini araştırmışlardır. Avrupa ülkelerindeki tarımda enerji tüketimi, ekonomik büyüme ve enerji değişimi arasındaki korelasyonu açıklamak için grafiksel yöntemler ve 2005-2018 dönemine ait verileri kullanarak tespitlerde bulunmuşlardır. Ancak Avrupa ülkeleri kullandıkları enerji açısından farklılık göstermektedir. Kullandıkları enerjinin temelinde sıvı yakıtlar, doğal gaz, elektrik ve yenilenebilir enerji vardır. Elde edilen birinci hipotezde tarımda büyük ölçüde yenilenebilir enerji kullanılmaktadır. İkinci hipoteze göre; tarımda kullanılan yenilenebilir enerji tüketimi artışı ekonomi parametreleriyle yakından ilişkili olduğu tespit edilmiştir. Yenilenebilir enerjinin kullanılmasının temelinde doğal çevreyle ilişkili olduğu sonucuna varılmıştır. Chandio ve ark. (2021), Çin ekonomisini inceledikleri araştırmalarında yenilenebilir ve yenilenemeyen enerji tüketimi, ekonomik büyüme ve tarımsal katma değer arasındaki ilişkileri analiz etmişlerdir. ARDL sınır testi, Granger nedensellik testi ve uzun dönem değişkenlerin uzun dönem ilişkilerini tespit etmek için FMOLS yöntemi kullanılmıştır. Çalışmada yenilenebilir enerji tüketimi çevresel kaliteyi ve ekonomik büyümeyi artırmakta, karbondioksit salınımını azaltmaktadır. Diğer taraftan yenilenemeyen enerji tüketimi ekonomik büyümeyi, tarımsal çıktıyı ve karbondioksit salınımını artırdığı sonucu tespit edilmiştir.

Ampirik çalışmalar bazı çıkarımları beraberinde getirmektedir. İlk olarak; gerek panel veri gerek se zaman serisi çalışmalarında değişkenler arasında asimetrik ilişkiler ele alınmamıştır. İkinci olarak; zaman serisi analizi kullanılarak Türkiye ekonomisini analiz eden çalışmaların çok az olduğu dikkat çekmektedir. Ayrıca bu çalışmalarda simetrik ilişkilerin simetrik testler ile araştırıldığı görülmektedir. Bu nedenle bu açılardan bakıldığında çalışmamız diğer çalışmalardan ayrışmakta ve literatüre önemli katkılar sunabileceği düşünülmektedir. Elde edilen bulgulara göre de farklı tavsiyelerde bulunmak mümkün olabilecektir.

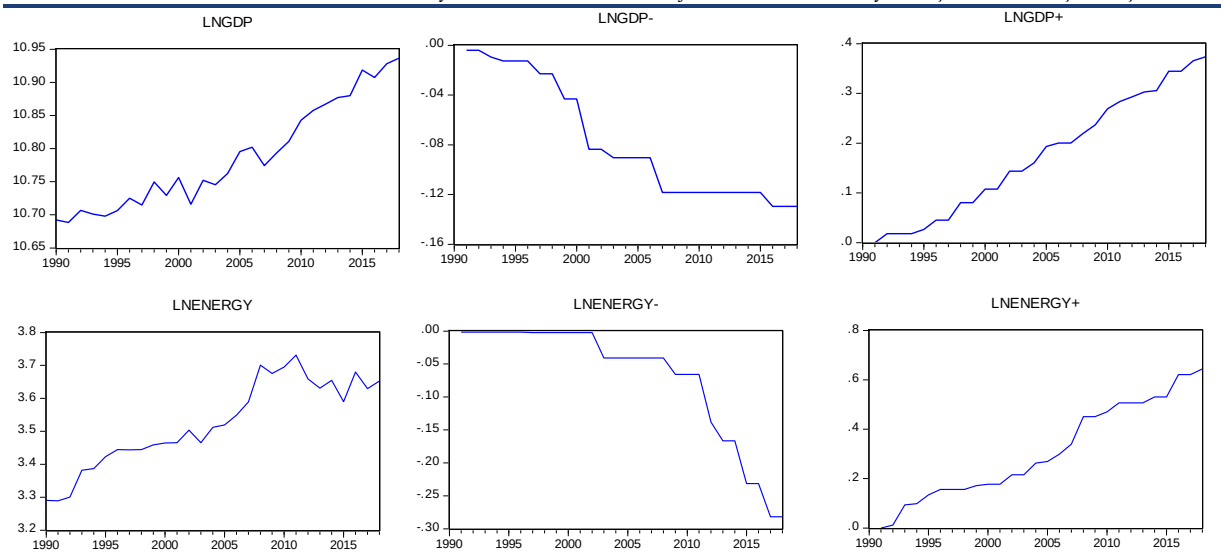
3. Model ve Veri Seti

Türkiye ekonomisi açısından tarımsal enerji tüketimi ve ekonomik büyüme arasındaki ilişkiyi asimetrik olarak test edebilmek için aşağıdaki gibi bir doğrusal regresyon denklemi dikkate alınmıştır:

$$LNGDP_t = \beta_0 + \beta_1 LNENERGY_t + u_t \quad \text{(Eş. 1)}$$

$$LNENERGY_t = \beta_0 + \beta_1 LNGDP_t + u_t \quad \text{(Eş. 2)}$$

Yukarıdaki modelde β_0 sabit terimi, u_t ise hata terimini göstermektedir. GDP ekonomik büyümenin ölçütü olarak kişi başına reel geliri (2010 sabit $ fiyatlarıyla), ENERGY tarımsal enerji tüketimini temsilen tarım sektöründe kullanılan toplam enerji tüketimini ifade etmektedir. Kişi başına reel gelir Dünya Bankası (WDI, 2022) veri sitesinden, tarımsal enerji tüketimi verileri ise Uluslararası Enerji Ajansından (IEA, 2022) elde edilmiştir. Bu çalışmada 1990-2018 dönemine ait yıllık veriler kullanılmıştır. Yıl aralığının 1990- 2018 olarak seçilmesi tarımsal enerji tüketimi verisinin 2018 yılında son bulmasından kaynaklanmaktadır. Tüm değişkenler logaritmaları alındıktan sonra analizlere dâhil edilmişlerdir. Bunun temel nedeni değişkenlerin katsayılarının elastikiyet olarak tahmin edilebilmesi ve yorumlanabilmesidir. Tarımsal enerji tüketimi ve ancak analiz konusu olan Türkiye, değişkenleri olan tarımsal enerji tüketimi (ENERGY) ve ekonomik büyüme (GDP) değişkenlerinin pozitif ve negatif bileşenlerinin (LNENERGY+, LNENERGY- ve LNGDP+,LNGDP-) zaman içindeki değişim grafikleri aşağıda sunulmuştur.



Şekil 1. Lnenergy +, lnenergy -, lngdp + ve lngdp– bileşenleri

Figure 1. Lnenergy+, lnenergy-,lngdp+,lngdp- componets

4. Metodoloji

Türkiye ekonomisinde tarımsal enerji tüketimi ile ekonomik büyüme arasındaki ilişkinin asimetrik olarak araştırıldığı bu çalışmada çok yönlü bir ekonometrik metodoloji kullanılmıştır. Birinci aşamada değişkenlerin birim kök (durağanlık) analizleri Arttırılmış Dickey-Fuller (ADF) (1981) ve Phillips-Perron (PP) (1988) testi ile yapılmıştır. Uzun dönemde aralarında anlamlı bir ilişkinin (eşbütünleşmenin) olup olmadığını tespit edebilmek için Johansen eşbütünleşme testi uygulanmıştır. Johansen eşbütünleşme testinde değişkenler arasında herhangi bir eşbütünleşmenin olmaması gerekmektedir. Çünkü analizin bir sonraki adım olan Hatemi-J ve Irandoust (2012) saklı eşbütünleşme testine geçilebilmesi için bu bir önkoşuldur. Daha sonra eşbütünleşme tespit edilmeyen değişkenler arasında bir saklı eşbütünleşmenin olup olmadığını belirleyebilmek için her bir değişken + ve - bileşenlerine ayrıştırılmaktadır. Elde edilen + ve - bileşenler Hatemi-J ve Irandaoust (2012) saklı eşbütünleşme testine tabi tutularak hangi bileşenler arasında anlamlı bir ilişki tespit edilirse, bu bileşenlerin uzun dönem katsayısı tahmin edilecektir. Bunun için de Phillips ve Hansen (1990) tarafından ortaya atılan FMOLS tahmincisi uygulanmıştır. Son ve üçüncü aşamada ise saklı eşbütünleşme tespit edilen değişkenlerin + ya da – bileşenleri arasında bir nedensellik ilişkisinin olup olmadığı Granger ve Yoon (2002) tarafından geliştirilen saklı hata düzeltme modeli yardımıyla araştırılmıştır. Böylece asimetrik bir nedenselliği varlığı tespit edilecektir.

4.1. Birim kök analizi

Zaman serisi çalışmalarında durağan olmayan değişkenler ile yapılan analizler sahte sonuçlar verebilmektedir. Bundan dolayı regresyon sonuçları değişkenler arasındaki ilişkiyi gerçek manada göstermeyecektir. Ayrıca modelde kullanılan değişkenlerin istatistiksel analizlere tabi tutmadan öncelikle tüm değişkenlerin durağanlık durumu tespit edilmelidir. Birim kök testleri ile durağanlık analizi gerçekleştirilmektedir (Wojciech ve Derek, 1999). Bu amaçla Dickey ve Fuller (1981) tarafından geliştirilen genişletilmiş Dickey-Fuller (ADF) testi uygulanmıştır. Bu test aşağıdaki modeli dikkate almaktadır.

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \gamma Y_{t-1} + \beta \sum_{1=1}^{n} \Delta Y_{t-1} + \varepsilon_t \qquad \text{(Eş. 3)}$$

Denklemde yer alan Y bağımlı değişkeni, Δ fark işlemcisini, t trend terimini, ε hata terimini temsil etmektedir.

Bu çalışmada ADF testinin yanı sıra Phillips ve Perron (1988) tarafından geliştirilen PP testi kullanılmaktadır. PP testinde test istatistiğinin hesaplanması için bazı non-parametrik düzeltmelere ihtiyaç duyulmaktadır. Bu nedenle otokoralesyon, test istatistiğinin asimtotik dağılımını etkilememektedir. ADF'den daha güçlü bir test olup ADF birim kök testi ile aynı asiptotik dağılıma sahiptir (Phillips ve Perron, 1988).

$$\Delta X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 t + \sum_{k=1}^{m} \beta_k \Delta X_{t-k} + u_t \qquad \text{(Eş. 4)}$$

PP ve ADF testi gibi elde edilen test istatistiği değerleri Mackinnon kritik değerleriyle karşılaştırılıp birim kök (durağlık) olup olmadığına karar verilmektedir.

4.2. Saklı eşbütünleşme analizi

Çalışmalarda kullanılan geleneksel eşbütünleşme testlerinde (Engle-Granger, Johansen, ARDL eşbütünleşme yaklaşımları gibi) eşbütünleşmenin araştırılmasında pozitif ve negatif şokların (bileşenlerin) etkisini aynı oranda kabul etmektedir. Granger ve Yoon (2002) bu varsayımı kabul etmeyerek serilerin normal düzeylerinde değil de + ve – şokları ya da bileşenleri arasında bir eşbütünleşmenin olabileceğini vurgulamışlar ve çalışmalarında Engle ve Granger, (1987) tarafından geliştirilen eşbütünleşme yaklaşımını uygulamışlardır. Bu yaklaşım daha sonraları Hatemi J ve Irondoust (2012) tarafından daha da geliştirilerek Johansen temelli bir saklı eşbütünleşme yaklaşımına dönüştürülmüştür. Bu test aşağıdaki denklemleri baz alır:

$$X_t = X_{t-1} + \varepsilon_t = X_0 + \sum_{i-1}^{t} \varepsilon_i \quad \text{(Eş. 5)}$$

$$Y_t = Y_{t-1} + \eta_t = Y_0 + \sum_{i-1}^{t} \eta_i \quad \text{(Eş. 6)}$$

Burada yer alan t =1, 2……,T dönemleri, ε_t ,η_t ,standart hataları, X_t ve Y_t serileri ise başlangış değerlerini göstermektedir. X_t ve Y_t değişkenlerinin pozitif ve negatif bileşenleri arasında eşbütünleşme ilişkisine bakılmaktadır. Aşağıdaki denklemler yardımıyla pozitif ve negatif bileşenler arasındaki saklı eşbütünleşme ilişkisi tanımlanabilir:

$$\varepsilon_i^+ = \max(\varepsilon_i, 0)\ \varepsilon_i^- = \min(\varepsilon_i, 0) \quad \text{(Eş. 7)}$$

$$\eta_i^+ = \max(\eta_i, 0)\ \eta_i^- = \min(\eta_i, 0) \quad \text{(Eş. 8)}$$

Bunu takiben 9 ve 10no'ludenklemlerdeki hata terimleri ε =ε^++ϵ^- ve η =η^++η^- şeklinde gösterilebilir. Bu seriler 5 ve 6 no'lu denklemlerde yazıldığında aşağıdaki denklemler oluşur:

$$X_t = X_{t-1} + \varepsilon_t = X_0 + \sum_{i-1}^{t} \varepsilon_i^+ + \sum_{i-1}^{t} \varepsilon_i^- \quad \text{(Eş. 9)}$$

$$Y_t = Y_{t-1} + \eta_t = Y_0 + \sum_{i-1}^{t} \eta_i^+ + \sum_{i-1}^{t} \eta_i^- \quad \text{(Eş. 10)}$$

4.3. Saklı hata düzeltme modeli (nedensellik analizi)

Değişkenlerin – ve + bileşenleri arasında bir saklı eşbütünleşmenin varlığı bir sonraki aşamada Granger ve Yoon (2002) tarafından ortaya konulan saklı hata düzeltme modeli kurulabilir ve bu model sayesinde nedensellik ilişkileri tahmin edilebilir. $X^t ve\ Y^t$ aralarında saklı eşbütünleşmenin olduğu iki seri ise bu seriler arasında saklı hata düzeltme modelleri nihai aşamada aşağıdaki gibi kurgulanabilir:

$$\Delta X_i^+ = \gamma_0 + \gamma_1 (X_{t-1}^+ - Y_{t-1}^+) + lags(\Delta X_{t-1}^+ - \Delta Y_{t-1}^+) + \varsigma_t \quad \text{(Eş. 11)}$$

$$\Delta Y_i^+ = \delta_0 + \delta_1 (X_{t-1}^+ - Y_{t-1}^+) + lags(\Delta X_{t-1}^+ - \Delta Y_{t-1}^+) + \varsigma_t \quad \text{(Eş. 12)}$$

Modeldeki hata düzeltme katsayılarının negatif ve istatistiki olarak anlamlı olması durumu kısa dönemde meydana gelen dengesizliklerin uzun dönemde giderileceği anlamına gelmektedir. Aynı zamanda bu durum serilerin + ya da – bileşenleri arasında uzun dönemde bir asimetrik nedenselliğin olduğuna kanıttır (Gündüz, 2020).

4.4. FMOLS tahmincisi

Bu çalışmada serilerin uzun dönem katsayılarının tahmininde Phillips ve Hansen (1990) tarafından literatüre kazandırılan tamamen modifiye edilmiş EKK(FMOLS) tahmin tekniğinden yararlanılmıştır. Geleneksel EKK tahmin tekniğine göre daha güçlü ve sağlıklı sonuçlar veren FMOLS tekniği küçük örneklem büyüklüklerinde iyi bir performans sergilemektedir. FMOLS tahmincisi aşağıdaki gibi formülize edilebilir:

$$\hat{\theta} = \begin{bmatrix} \beta \\ \hat{\gamma}_1 \end{bmatrix} = (\sum_{t=2}^{T} Z_t Z_t')^{-1} \left(\sum_{t=2}^{T} Z_t y_t^+ - T\left[\hat{\lambda}_{12}^+\right] \right) \quad \text{(Eş. 13)}$$

Burada $Z_t = (X_t', D_t')'$' şeklinde ifade edilir. Bu tahmin tekniğinde uzun dönem kovaryans matrisleri (Ωˆve Λˆ) kalıntılar ($u_t = (u_{1t}, u_{2t}')'$) kullanılarak analiz edilir.

5. Bulgular ve Tartışma

Ampirik bulgulara ilk olarak çalışmada kullanılan her bir değişkene ilişkin tanımlayıcı istatistiklerden başlanmış olup elde edilen sonuçlar *Tablo 2*'de sunulmuştur. 1980-2018 döneminde tarımsal enerji tüketimi ortalama değeri 3.52, ekonomik büyüme ise 10.78 olarak gerçekleşmiştir. Çarpıklık katsayısı için tarımsal enerji tüketimi -0.17 sıfırdan küçük olduğu için sola çarpıktır. Ancak ekonomik büyüme çarpıklık katsayısı pozitif yani 3 ten küçük olduğundan sağa çarpık olarak tespit edilmiş ve normal dağılıma göre diktir. Değişkenlerin standart hataları sırasıyla 0.13 ve 0.07; maksimum değerleri ise 3.73 ve 10.93 olarak ifade edilebilir.

Tablo 3'te ise modelde yer alan değişkenlerin korelasyon katsayıları yer almaktadır. Değişkenlerin korelasyon katsayısı (0.844), pozitif ancak 1'e yakındır. Bu sonuç iki değişken arasında pozitif ve güçlü bir korelasyonun olduğunu ortaya koymaktadır.

Tablo 2. Değişkenlerin tanımlayıcı istatistikleri

Table 2. Descriptive statistics of variables

Değişkenler/İstatistikler	Ortalama	Medyan	Max.	Min.	St. Hata	Çarpıklık	Basıklık
LNENERGY	3.52	3.51	3.73	3.28	0.13	-0.17	1.98
LNGDP	10.78	10.76	10.93	10.28	0.07	0.50	1.92

Tablo 3. Değişkenlerin korelasyon matrisleri

Table 3.Correlation matrix of variables

Değişkenler	LNENERGY	LNGDP
LNGDP	1	-
LNENERGY	0.844	1

Tarımsal enerji tüketimi ile ekonomik büyüme değişkenlerinin durağanlık analizinin ADF ve PP test sonuçları *Tablo 4*'de sunulmaktadır. Birim kök test sonuçlarına göre; değişkenlerin düzey değerlerinde durağan olmadığı görülmektedir. Ancak serilerin birinci farkları alınarak yapılan durağanlık testi değişkenlerin birinci farkında durağan olduğunu ortaya koymaktadır. Bu sonuç değişkenlerin eşbütünleşme analizi için Johansen testi ile Hatemi J-Irondoust saklı eşbütünleşme testinin kullanımına ve saklı hata düzeltme modelinin kurulmasına imkân tanımaktadır.

Tablo 4: Birimkök test sonuçları

Table 4. Unıt root test results

	ADF		PP	
Değişkenler	Sabitli	Sabitli-trendli	Sabitli	Sabitli-trendli
LNGDP	1.087	-1.506	1.562	-2.724
LNENERGY	-1.585	-3.012	-1.594	-2.123
ΔLNGDP	-9.123***	-9.483***	-9.047***	-15.587***
ΔLNENERGY	-7.073***	-7.738***	-6.914***	-7.738***

Not: ADF testinde optimal gecikmeuzunluğu AIC kriteri kullanılarak otomatik olarak belirlenmiştir. PP testinde band genişliği için Newey-West(1994) metodu kullanılmıştır. ***, %1 düzeyinde anlamlılığı ifade eder.

Değişkenlerin birinci farkında durağanlık göstermesi seriler (+ ve – bileşenler) arasında eşbütünleşmenin varlığını test edebilmek için Johansen eşbütünleşme testinin kullanımına izin vermektedir. Johansen eşbütünleşme testi için öncelikle model için gecikme uzunluğunun belirlenmesi gerekir. Yapılan VAR analizi sonucuna göre, *Tablo 5*'ten de görüleceği üzere, uygun gecikme uzunluğu olarak bulunmuş olup bu sonuç bir sonraki aşamada yani Johansen eşbütünleşme analizinde kullanılmıştır.

Tablo 5: VAR gecikme uzunluğu belirleme

Table 5. Determination of VAR lag length

Gecikme uzunluğu	LR	FPE	AIC	SIC	HQ
0	NA	2.39e-05	-4.965	-4.868	-4.937
1	84.929	8.12e-07	-8.350	-8.059	-8.266
2	10.792	6.66e-07*	-8.556*	-8.072*	-8.417*
3	0.370*	9.04e-07	-8.268	-7.590	-8.073

Not: *, optimal gecikme uzunluğunu ifade eder.

Modele dâhil edilen tarımsal enerji kullanımı ve ekonomik büyüme değişkenleri arasında bir eşbütünleşmenin varlığı Johansen eşbütünleşme testi ile sınanmaktadır. Bu test sonucunda öncelikle seriler arasında bir eşbütünleşmenin olmaması gerekiyor ki serilerin + ve – bileşenleri arasında bir saklı eşbütünleşmenin varlığı araştırılabilsin. *Tablo 6*'da görülen sonuçlar serilerin normal değerleri arasında bir eşbütünleşmenin yani bir uzun dönem ilişkisinin olmadığını göstermektedir. Bu nedenle serilerin + ve – bileşenleri arasında saklı eşbütünleşmenin olup olmadığı Hatemi J-Irondoust testi yardımıyla incelenmektedir. Bunun ön şartı serilerin + ve – bileşenlerinin birinci farkında durağan olmasıdır. Bu amaçla gerçekleştirilen birim kök analizi sonuçları *Tablo 7*'de sunulmuştur. Bulgular serilerin + ve - bileşenlerinin düzeyde durağan olmadığını birinci farkları alındığında durağan hale geldiğini ortaya çıkarmaktadır. Bu durum serilerin birinci farkında durağan olduğu anlamına gelmektedir. Bu durum aynı zamanda seriler arasında saklı bir eşbütünleşme analizi yapılmasına izin vermektedir.

Tablo 6. Johanseneşbütünleşme test sonuçları

Table 6. Johansen cointegration test results

	İz istatistiği	Max. öz değer istatistiği
R=1	12.428	8.182
R≤1	4.246	4.246

Tablo 7. Serilerin birim kök test sonuçları (+ ve - bileşenleri)

Table 7. Unıt root test results of series (+ and –components)

	ADF		PP	
Değişkenler	Sabitli	Sabitli-trendli	Sabitli	Sabitli-trendli
LNGDP+	0.980	-3.875	0.252	-3.872
LNGDP-	-1.132	-1.356	-1.141	-1.376
LNENERGY+	-0.196	-2.162	-0.168	-2.192
LNENERGY-	2.564	-0.711	2.506	-0.359
ΔLNGDP+	-8.393***	-8.553***	-8.356***	-8.853***
ΔLNGDP-	-6.207***	-6.326***	-6.120***	-6.241***
ΔLENERGY+	-6.329***	-6.197***	-6.298***	-6.171***
ΔLENERGY-	-5.313***	-7.169***	-5.310***	-7.239***

Not: ***, %1 düzeyinde anlamlılığı ifade eder.

Bileşenlerine ayrıştırılan değişkenlerin birim kök analizleri yapılmıştır. Daha sonra söz konusu bileşenlere Johansen eşbütünleşme testi uygulanmış ve bu teknik Hatemi J-Irandoust (2012) saklı eşbütünleşme testi olarak bilinmektedir. *Tablo 8*'den elde edilen bulgulara göre; tarımsal enerji tüketimi + serisi ile ekonomik büyüme + serisi arasında eşbütünleşmenin varlığı tespit edilmiştir. Ancak tarımsal enerji tüketimi - serisi ile ekonomik büyüme - serisi arasında uzun dönemde bir ilişkinin varlığı tespit edilememiştir. Değişkenlerin – serilerinde eşbütünleşmenin varlığı söz konusu olmadığı için bundan sonraki aşamada bu seriler için uzun dönem katsayıları ve nedensellik ilişkisi tahmin edilmemiştir.

Türkiye ekonomi dikkate alınarak yapılan analizde serilerin + bileşenleri arasında uzun dönemli bir ilişkinin (bir eşbütünleşmenin) tespit edilmesinden sonra söz konusu serilerin uzun dönem katsayıları FMOLS tahmin tekniğiyle tahmin edilmiş ve *Tablo 9*'da gösterilmiştir. Modelde bağımsız değişken olarak tarımsal enerji tüketimi + serisi, bağımlı değişken olarak ise ekonomik büyüme + serisi alınmıştır. Bu durumda tarımsal enerji tüketimi +

serisi katsayısı 0.519 olarak bulunmuştur. Elde edilen bu sonuç tarımsal enerji tüketimi + serisinde meydana gelen %1'lik bir artışın, ekonomik büyüme + serisinde 0.519 oranında bir artış sağladığı anlamına gelmektedir. Diğer taraftan ekonomi büyüme + serisi ile tarımsal enerji tüketimi + serisi arasında da pozitif bir ilişki söz konusudur. Bu ilişki katsayısı 1.332 olarak belirlenmiştir.

Tablo 8.Hatemi J- Irandoust saklı eşbütünleşme analiz sonuçları (+ ve - bileşenleri)

Table 8. Hatemi-j Irandoust hidden cointegratıon analysis results (+ and –components)

	İz istatistiği	Max. öz değer istatistiği
LNERGY+LNGDP+		
R=1	26.873**	19.663**
R≤1	7.210	7.210
LNENERGY- LNGDP-		
R=1	8.284	7.857
R≤1	0.426	0.426

Not: ** % 5 düzeyinde anlamlılığı ifade eder.

Tablo 9. Uzun dönem katsayı tahminleri (tahmin yöntemi: FMOLS)

Table 9. Long-run coefficient estimates (estimation method: FMOLS)

	LNENERGY+	LNGDP +
Katsayılar	0.519***	1.332***

Not: ***, %1 düzeyinde anlamlılığı ifade eder.

Ampirik analizde tarımsal enerji tüketimi + serisi ile ekonomik büyüme + serisi arasında uzun dönem ilişkisinin varlığı tespit edildiğinden dolayı nedensellik analizi olan saklı hata düzeltme modelinde de bu seriler dikkate alınmış, çıkan sonuçlar *Tablo 10*'da sunulmuştur. Bağımlı değişken tarımsal enerji tüketimi+ serisi, bağımsız değişken ise ekonomik büyüme + serisi alındığında hata düzeltme katsayısı olan ECT'nin -0.331 yani negatif ve istatiksel olarak anlamlı olduğu görülmektedir. Bu durum ekonomik büyüme + serisinden tarımsal enerji tüketimi + serisine doğru uzun dönemli bir asimetrik nedenselliğin varlığını ortaya koymaktadır.

Tablo 10. Saklı hata düzeltme modeli tahmin sonuçları (bağımlı değişken: lnenergy+)

Table 10. Hidden error correction model prediction results (dependent variable: lnenergy+)

Değişkenler	Katsayılar	Standart Hata	t-istatistiği	Olasılık
Sabit	0.023***	0.005	4.547	0.000
ECT_{t-1}	-0.331**	0.134	-2.560	0.016

Not: ***ve**sırasıyla %1 ve % 5 düzeyinde anlamlılığı ifade eder.

Bağımlı değişkeni ekonomik büyüme + serisi, bağımsız değişkeni tarımsal enerji tüketimi + serisi seçildiğinde kurulan saklı hata düzeltme modeli tahmin sonuçları *Tablo 11*'de sunulmuştur. Elde edilen ampirik bulgular neticesinde saklı hata düzeltme katsayısı ECT hesaplanamadığından dolayı söz konusu modele dahil edilen bileşenler arasında bir asimetrik nedenselliğin varlığı tespit edilememiştir. Böyle bir durumda tarımsal enerji tüketimi + serisinden ekonomik büyüme + serisine doğru bir nedenselliğin varlığına hükmedilememiştir.

Tablo 11. Saklı hata düzeltme modeli tahmin sonuçları (bağımlı değişken: lngdp+)

Table 11. Hidden error correction model prediction results (dependent variable: lngdp+)

Değişkenler	Katsayılar	Standart Hata	t-istatistiği	Olasılık
Sabit	0.020	0.003	6.056	0.000
GDP_{t-1}	-0.493	0.177	-2.772	0.010

6. Sonuç

Enerji tüketimi diğer tüm sektörlerde olduğu gibi tarım sektöründe de uzun zamandır bir artış eğilimi sergilemektedir. Enerji tüketimindeki bu artış pek çok ekonomik faaliyeti de olumlu yönde etkilemektedir. Tarımsal enerji tüketimi tarım sektörünün gelişiminde önemli bir unsur olduğu gibi ülke ekonomisinin de büyümesinde önemli bir rol oynayabilecektir. Bu nedenle bu çalışmada tarımsal enerji tüketiminin ekonomik büyüme üzerindeki etkisi Türkiye örneğinde 1990-2018 periyodunda araştırılmıştır. Türkiye ekonomisi üzerine

yapılan ekonometrik uygulamada değişkenlerin durağanlık analizi ADF ve PP birim kök testleriyle, değişkenler arasındaki eşbütünleşmenin belirlenmesinde ise Johansen testinden istifade edilmiştir. Johansen testi sonuçları seriler arasında bir eşbütünleşme tespit edememiştir. Bu nedenle seriler arasında saklı bir eşbütünleşmenin var olabileceği düşüncesiyle her bir değişken + ve – bileşenlerine ayrıştırılarak bu + ve – bileşenler arasında bir eşbütünleşmenin olup olmadığı Hatemi-j ve Iranoust saklı eşbütünleşme testi ile araştırılmıştır.

Bulgular değişkenlerin + bileşenleri arasında bir eşbütünleşmenin olduğunu ortaya koymuştur. Bu sonuç bizi değişkenlerin + bileşenlerine ilişkin uzun dönem katsayılarının tahmin edilmesine götürmüştür. Bu amaçla kullanılan FMOLS tahmin tekniği tarımsal enerji tüketimi + bileşeni katsayısının (0.519) pozitif ve istatistiki olarak anlamlı bulduğundan uzun dönemde tarımsal enerji tüketimi + bileşeni ile ekonomik büyüme + bileşeni arasında pozitif bir ilişkinin olduğuna hükmedilmiştir. Bu sonuç, tarımsal enerji tüketimi + serisinde meydana gelen %1'lik bir artışın ekonomik büyüme + serisini uzun dönemde 0.519 oranında artırdığı şeklinde yorumlanabilir. Diğer taraftan ekonomik büyüme + bileşeninin pozitif ve istatistiki olarak anlamlı olması ekonomik büyüme + bileşeni ile tarımsal enerji tüketimi + bileşeni arasında pozitif bir ilişkinin varlığına işaret etmektedir. Saklı hata düzeltme modeli sonuçlarına göre ise ekonomik büyüme + serisinden tarımsal enerji tüketimi + serisine doğru uzun dönemli nedensellik tespit edilmiştir.

Literatürde pek çok çalışma enerji tüketiminin ekonomik büyümeyi desteklediği sonucuna ulaştığı gibi tarımsal enerji tüketiminin de ekonomik büyümeyi pozitif etkilediği yönünde bulgular sunmaktadır. Çalışmamızda tarımsal enerji tüketimi + bileşeninin ekonomik büyüme + bileşenini pozitif etkilediği bulgusu aslında tarımsal enerji tüketimi ile ekonomik büyüme arasında pozitif bir ilişkinin varlığına bir kanıt olarak değerlendirilebilir. Bu durum aslında enerji-büyüme konusundaki dört temel hipotezden biri olan "koruma hipotezi" ni destekleyen bir kanıt olarak değerlendirilebilir. Bu çalışmada gerçekleştirilen eşbütünleşme analizleri sonucunda literatüre paralel olarak tarımsal enerji ile ekonomik büyüme arasında uzun dönemde bir ilişki olduğu tespit edilmiştir. Literatürde tarımsal enerji tüketimin ekonomik büyümeyi pozitif etkilediği sonucuna ulaşılmıştır. Genel anlamda bu çalışmanın sonuçları ampirik literatürü destekler nitelikte olup ve Kraft ve Kraft (1978), Karkacier ve ark. (2006), Adom (2011), Mirza ve Kanwal (2017), Yanıktepe ve ark. (2021) ve Rahman (2021) gibi iktisatçıların daha önce yaptıkları çalışmalarının nedensellik bulgularıyla eşleşmektedir. Ancak Altiner (2019), Tuna ve Tuna (2019) gibi yazarlar ise enerji tüketimi ile ekonomik büyüme arasında herhangi bir nedensellik tespit etmemişlerdir.

Tarım sektörü ülke ekonomilerine ve insan yaşamına sağladığı katkılar ile önemli bir yere sahip olduğu gibi sürdürülebilir bir gelişme için de çok önemli olduğu bilinmektedir. Özellikle sanayi sektörüne hammadde ve sermaye sağlaması, nüfusun gıda ihtiyacını karşılaması, ihracat yolu ile ülkeye döviz girdisi sağlaması ve stratejik öneme sahip olması gibi özellikleri tarım sektörünü vazgeçilmez kılmaktadır. Modern tarım teknolojinin gelişmesi ile birlikte tarımsal üretim süreçlerinde meydana gelen değişim ve gelişmeler ve makine kullanımının yaygınlaşması birlikte tarımda enerji kullanımını gündeme getirmiştir. Tarımsal enerjinin kullanımı verimliliği ve üretimi artırmıştır. Ancak enerji tüketimi tarım sektöründe önemli bir maliyet yaratmaktadır. Maliyetleri düşürmek söz konusu olduğunda fosil yakıtlardan ziyade güneş, su ve rüzgar enerjisi gibi yenilenebilir enerji kaynaklarından istifade etmek zorunluluk arz etmektedir. Bu nedenle hükümetlerin fosil yakıtlardan yenilenebilir enerji kaynaklarına olan dönüşümü kolaylaştıracak şekilde teşvik ve önlemler alması gerekmektedir. Bu çerçevede pek çok gelişmiş ülkenin tarım sektörünü gelişimi için yenilenebilir enerji kaynaklarına dönük yatırımları ve projeleri desteklediği görülmektedir. Bu şekilde tarım sektörü artan enerji ihtiyacını daha düşük maliyetle ve çevreye duyarlı olacak şekilde karşılamış olacaktır. Türkiye geleneksel enerji kaynakları açısından dışarıya bağımlı olduğundan ve ülkenin coğrafik konum itibariyle yenilenebilir enerji kaynakları açısından çeşitlilik gösterdiğinden orta ve uzun vadede tarım sektöründe yenilenebilir enerji kaynaklarını kullanmak oldukça önemli bir gerçek olacaktır.

Bu çalışmada kullanılan yönteme uygun olarak iki değişken arasındaki ilişki incelenmiştir. Aynı zamanda sonraki çalışmalara yol gösterebilir. Her çalışmada olduğu gibi bu çalışmanın da kısıtları bulunmaktadır. Bu kısıtlar daha sonra yapılan çalışmalara ışık tutacaktır. Yazarlar farklı asimetrik veya simetrik yöntemler kullanarak, değişkenlerin sayısını artırarak ya da araştırma bölgesini değiştirerek farklı ampirik sonuçlar elde edebilirler. Bu farklı sonuçlar doğrultusunda farklı öneri politikaları sunabilirler.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effect of Almond Pulp Addition on Physical, Chemical and Functional Properties of Tarhana*

Badem Pulpu İlavesinin Tarhananın Fiziksel, Kimyasal ve Fonksiyonel Özelliklerine Etkisi

Ezgi ŞENSOY[1], Zekai TARAKÇI[2*]

Abstract

In this study, almond pulp was added to tarhana to increase its nutritional value. For this purpose, after grinding the almonds, the oil was reduced and almond pulp was added to the tarhana mix at the rates of 0% (control), 5%, 10%, 15%, 20%, 25% and 30%. According to the research data, pH and titration acidity values of tarhana increased significantly with the increase of almond pulp addition ($p<0.05$). It was observed that protein, ash and fat ratios increased significantly with the increase of almond ratio in tarhana ($p<0.05$). While increasing the almond ratio significantly decreased the whiteness (L*) values of tarhana ($p<0.05$), it was determined that the redness (a*) and yellowness (b*) values increased significantly ($p<0.05$). While there was no significant change in water holding capacity with increasing almond content in tarhana ($p>0.05$), it was determined that the almond additive increased the foaming capacity and foam stability statistically ($p<0.05$). It was determined that the viscosity of tarhana decreased statistically significantly as the almond content increased ($p<0.05$). It was determined that the almond pulp added to the tarhana mix increased the total phenolic substance and antioxidant activity values significantly ($p<0.05$). It was determined that almond pulp added tarhana samples had a positive effect on sensory parameters. Tarhana samples with 25% and 30% almond pulp added were found to be the most popular soups in terms of taste and aroma. Tarhana soups containing 15% almond pulp are the most preferred in terms of fragrance; Tarhanas containing 5% pulp were preferred in terms of color and consistency. As a result, it was determined that the addition of almond pulp positively affected the physical, chemical and rheological properties of tarhana. It has been determined that the best rate of almond pulp to be used in tarhana production is 30%.

Keywords: Tarhana, Almond pulp, Antioxidant activity, Total phenolic, Functional properties

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Öz

Bu çalışmada, besin değerini artırmak için tarhanaya badem posası ilave edilmiştir. Bu amaçla bademler öğütüldükten sonra yağı azaltılmış ve tarhana miksine % 0 (kontrol), % 5, % 10, % 15, % 20, % 25 ve % 30 oranlarında badem pulpu olarak ilave edilmiştir. Araştırma verilerine göre, badem pulpu ilavesinin artmasıyla tarhananın pH ve titrasyon asitliği değerleri önemli derecede yükselmiştir ($p<0.05$). Tarhanada badem oranının artmasıyla protein, kül ve yağ oranlarının önemli ölçüde arttığı gözlenmiştir ($p<0.05$). Badem oranının arttırılması tarhananın beyazlık (L*) renk değerlerini önemli derecede düşürürken ($p<0.05$), kızarıklık renk (a*) ve sarılık (b*) renk değerlerin anlamlı olarak arttığı belirlenmiştir ($p<0.05$). Tarhana örneklerinde artan badem pulpu içeriği ile su tutma kapasitesinde önemli bir değişiklik olmazken ($p>0.05$), badem posası ilavesinin tarhana çorbalarında köpürme kapasitesini ve köpük stabilitesini istatistiki olarak önemli derecede arttırdığı belirlenmiştir ($p<0.05$). Badem pulpu içeriği arttıkça tarhana örneklerinin viskozitesini istatistiksel olarak önemli ölçüde azaldığı tespit edilmiştir ($p<0.05$). Tarhana miksine ilave edilen badem pulpu çorba örneklerinin toplam fenolik madde ve antioksidan aktivite değerlerini önemli derecede ($p<0.05$) arttırdığı istatiksel olarak tespit edilmiştir. Badem posası katkılı tarhana örneklerinin duyusal parametreler üzerinde olumlu etkisi olduğu belirlenmiştir. % 25 ve % 30 badem pulpu katkılı tarhana örneklerinin tat ve aroma açısından en popüler çorbalar olduğu görülmüştür. %15 badem posası içeren tarhana çorbaları ise koku açısından en çok tercih edilenlerdir; renk ve kıvam açısından ise %5 posa içeren tarhana çorba örnekleri tercih edilmiştir. Sonuç olarak badem posası ilavesinin tarhananın fiziksel, kimyasal ve reolojik özelliklerini olumlu yönde etkilediği belirlenmiştir. Tarhana üretiminde kullanılacak en iyi badem pulpu oranının %30 olduğu tespit edilmiştir.

Anahtar Kelimeler: Tarhana, Badem pulp, Antioksidan aktivite, Toplam fenolik, Fonksiyonel özellik

1. Introduction

Recently, as consumer awareness has grown, it has become necessary to experiment with alternative methods of food processing and preservation in order to meet consumer demand for natural products. These methods, which include fermentation, are extremely important in biotechnological production and conservation (Erbaş et al., 2006). Fermented foods are reliable products; taste and aroma constitute another factor to be consumed (Daglioglu et al., 2002). Fermented foods produced in comparison with the ingredients in their compositions are nutrients that had a long shelf life with their nutritional and sensory properties (Tamime and O'Connor, 1995; Gotcheva et al., 2001). Tarhana is a highly nutritious food that is characterized by the lactic acid fermentation process (Temiz and Pirkul, 1991). Tarhana is thought to have originated with Turks and Mongols who migrated from Central Asia and were brought to Anatolia, the Middle East, Hungary, and Finland, where they became known and consumed. Tarhana is referred to as kish in Arab countries, 'tahonya' in Hungary, 'talkuna' in Finland 'turkhana' in Bulgaria, and 'turkhana' in Serbia (Yıldırım and Ercan, 2004). Tarhana regulates the intestinal system with fibrous components and provides weight control. Tarhana contains probiotic bacteria and beneficial yeasts that help to strengthen the immune system (Yıldırım and Güzeler, 2016). A lot of research has been done on Tarhana. Some of these include the formulation of tarhana was found to be a product suitable for enrichment with various foods. In this study, tarhana was enriched for nutritional, sensory, and structural enrichment (Tarakçı et al., 2013). As fruit additions, cranberry (Koca et al., 2006), quince (Gökmen, 2009), and carob (Herken and Aydin, 2015) have been used. In this study, almond fruit pulp, a rich source of phytosterols (Tasan et al., 2006), was used as a contribution to tarhana production. Almond is the most produced tree nut globally (Sahin et al., 2022) and used in many fields as a side component in the food sector thanks to its rich nutritional potential and sensory flavour. The objective of this study was to incorporate the almond pulp into traditional tarhana formula and to compare some physical, chemical, functional, structure and sensory properties of the products.

2. Materials and Methods

Wheat flour, working yogurt, tomato paste, fresh yeast, mint, nectarine, red pepper, salt, and almond pulp (dry matter: 95.58%, protein: 23.92%, fat: 45.99%, ash: 3.36%, total phenolic content: 3.16 mg GAE/g, and antioxidant capacity: 0.46 mg TE/g) were the ingredients used to make Tarhana samples. Physical, chemical, and sensory analyses were performed in Ordu University Faculty of Agriculture Food Engineering Laboratories.

2.1 Tarhana Production

In the study, 0% (K), 5% (B5), 10% (B10), 15% (B15), 20% (B20), 25% (B25), 30% (B30) almond pulps were added to Tarhana samples. The formulation specified in *Table 1* refers to the control group (0%). Tarhana varieties are produced in 21 samples, 3 replicates.

2.2 Preparation of Almond (Grinding)

Unsalted, raw almonds obtained from the Ordu province market were first broken down and divided into smaller pieces in a food processor. In the cold press oil machine, the oil amount of almond was reduced. After being ground in a food processor to separate them into smaller particles, the oil-reduced almonds were prepared for use as additions.

2.3 Preparation of Tarhana Samples

The raw material samples and quantities used in tarhana production are shown in *Table 1*. While the almond ratio increased in the product formulations, the other input ratios remained constant. Before chopping the onions in the food processor, tomato paste, dried mint, red pepper, and salt were mixed. After prebaking the mixture, water was added and it was cooked for a while. When the temperature of the obtained mortar decreased to 20°C, flour, yoghurt, yeast and almonds were added. Kneaded for 10 minutes to ensure homogeneous dough structure. The prepared tarhana doughs were allowed to ferment for 30 hours at 30°C. Fermented tarhana doughs were brought into almond-sized pieces on the drying tray. The fermented tarhana doughs were dried in a fan oven (Nucleon, NST-120, Ankara) at 52°C until the moisture content reached 12%, before being ground and pulverized.

Table 1. Standard Tarhana formulation

Material	Portion (%)	Quantity
Wheat Flour	50	500
Yoghurt	25	250
Onion	12	120
Tomato paste	6	60
Salt	4	40
Fresh yeast	1	10
Red pepper	1	10
Powdered mint	1	10

2.4 Chemical Analyses of Tarhana

Dry matter analyses; In the analysis, the method of James (1995) was modified and the drying oven was previously brought to a constant weight at 105°C (Nucleon, NST-120, Ankara) and 5 g of sample was weighed into it. Ash analyses; in the analysis, James (1995) method was modified and 3-5 g of sample weighed into porcelain crucibles at 550±5°C temperature until the formation of white color. Color analyses; Color analysis of Tarhana samples was performed with a color measurement device (Minolta, CR-400, and Osaka, Japan). (L*; 100 = white, 0 = black), redness; (a*; + red and -green) and jaundice; (b*; +yellow and -blue) measurements were taken in prepared tarhana soup samples (Zhu et al., 2008). Total Fat analysis; Soxhelet extraction method was used to determine the fat content of the samples (James, 1995). The tarhana samples were boiled by distillation in the extraction apparatus (Velp Scientifica, SER 148, and Usmate, Italy). The pH analysis; to determine the pH of the 5 g tarhana pulp sample was weighed into a beaker and the pH was measured with a digital pH meter (Mettler Toledo, Seven Compact S210) at 25°C (Ibanoglu et al., 1995). Titratable Acidity Analysis: Titration was continued with 1-2 drops of 1% phenolphthalein and 0.1 NaOH solution until the mixture became pink (İbanoğlu et al., 1999). Protein Analysis; The Kjeldahl method was used to determine the protein content (James, 1995).

2.5 Functional Properties Analyses

Viscosity Analysis; 10 g of dry tarhana sample was weighed into a glass beaker and 150 ml of distilled water was added. The sample was cooked by stirring for 10 minutes, thereby gelatinizing the starch. The samples were poured into the sample cup of the viscometer (AND, SV-10, Tokyo, Japan) while hot. Measurements were performed at 30°C, 45°C and 60°C (Tarakçı et al., 2013). Water Retention Capacity Analysis; 3 g tarhana sample was weighed into centrifuge tubes and 15 ml of distilled water was added. The solution was stirred in a shaking incubator (Infors Ht Ecotron) for 1 minute at 120 rpm, earth 15 minutes for 60 minutes. It was then centrifuged at 4,000 rpm for 20 minutes (2-6 Sigma, 3K30 and Steinheim, Germany). The weight of the liquid fractions was determined at the end of the process. The value in grams of water absorbed by 1 g tarhana is called water-holding capacity (Tarakçı *et al.*, 2013). Foaming Capacity and Foam Stability Analysis; Following the placement of the centrifuge tubes, 20 ml of distilled water was added to 4 g of tarhana. The mixture was homogenized at 120rpm for 20 minutes in a shaking incubator (Infors Ht Ecotron), then placed in a centrifuge and centrifuged at 4000 rpm for 20 minutes (2-6 Sigma, 3K30, Steinheim, Germany). After this process, tarhana samples were removed from the centrifuge and filtered using filter paper (Whatman No. 1). The filtered samples were whipped at high speed with the Waring Blender (Torrington, CT, USA) for 2 min. The foam level of the samples transferred slowly and carefully to the measuring cylinder was recorded after 10 seconds. The ratio of the resulting foam volume (ml) to the solution volume (ml) was defined as the foam capacity (Tarakçı et al., 2013). Total Phenolic Analysis of Tarhana Samples; the method used by Xu and Chang (2007) for the total phenolic content analysis was modified. After 3 g of tarhana sample was homogenized with 10 ml of water, it was kept in a water bath of 25°C for 30 minutes. Samples were centrifuged at 4000 rpm for 10 min and filtered (Whatman no. 1). After taking 300µl of the filtrate into the tubes, 4300µl of water and 100µl of Folin Ciocalteu reagent were added and left for 2 minutes. Then 300µl 7.5% (w/v) Na_2CO_3 solution was added to the samples. The samples were vortexed and kept in the dark for 2 hours. At the end of the time, the absorbance of the spectrophotometer was read at 760 nm (UV-VIS Shamadzu UV mini-1240). Antioxidant Analysis of Tarhana Samples: For the antioxidant activity analysis of Tarhana samples, the method used by Demirkol and Tarakçı (2018) was modified. The 3g of tarhana samples were homogenized with 10ml of methanol and then placed in a water bath of 25°C for 30 minutes. After centrifuging the samples at 4000 rpm for 20 minutes, they were filtered through Whatman No.1 filter paper.50µl of the obtained

filtrate was taken and 1000µl of DPPH (1, 1-Diphenyl-2-picrylhydrazyl radical) reagent was added. At the end of the period, absorbance values of the samples were read on the spectrophotometer at 515nm wavelength.

2.6 Sensory Analysis of Tarhana Samples

Sensory analysis performed according to 100 g tarhana sample, 1.5 L distilled water, 40 g oil, and 10 g salt were mixed and the mixture is cooked in the steel pot at medium heat for 5 minutes while stirring. The cooked samples were kept in an oven at 60°C and presented to the panelists in porcelain bowls. Tarhana soups were served by faculty members and students (5 males, 5 females) in the Faculty of Agriculture who were between 20-40 years old and had no obstacles to sensory testing; color, odor, consistency, taste-aroma, and general acceptability characteristics were evaluated using the sensory form over 10 points (Anil *et al.*, 2020).

2.7 Statistical Analysis

For statistical analysis, the one-way ANOVA method was used with the Minitab 18 package program. as a result of variance analysis. The results are presented in tables.

3. Results and Discussion

3.1 The pH change was caused by the addition of almond pulp to Tarhana

The relationship between lactic acid bacteria and yeasts plays an important role in the production of Tarhana dough. Lactic acid bacteria are responsible for the increase of acidity; yeasts are responsible for the production of CO_2 and alcohol, the swelling of the dough, and its aromatic development. Although a variety of microorganisms are available at the beginning of fermentation, acid-producing lactic acid bacteria and acid-tolerant yeasts become dominant in later stages of fermentation (Şimşek et al., 2017). *Table 2* shows the pH analysis results for Tarhana. The highest pH value was determined as 5.32 in the group containing 30% almond pulp. The lowest pH value was found in the control group with a pH value of 4.65. During the fermentation period, it was determined that the pH value of Tarhana samples decreased because Tarhana dough, particularly yogurt bacteria and fermentable sugars, increased the amount of acid in the environment and thus reduced the pH value as a result of the effect of fermentable sugars on metabolites, particularly organic acids (Erbas et al., 2006). The effect of almond rate on pH was found to be statistically significant. ($p < 0.05$). During the fermentation of Tarhana, the production of acid occurs as a result of the activity of lactic acid bacteria and yeasts in the content of yogurt (Özdestan and Üren, 2013). Addition of yoghurt in the Tarhana formulation, the number of lactic acid bacteria increases, results in more lactic acid in the final product (İbanoğlu et al., 1999). Lactic acid fermentation protects Tarhana against mold growth and creates microbial safety (Leroy and De Vuyst, 2004).

When the Tarhana groups were compared, a statistically significant difference was found between the samples in terms of titratable acidity ($p<0.05$). As a result, it was discovered that adding almond pulp to Tarhana increased its acidity value. It is estimated that the free fatty acids released by hydrolysis and the high oil content in almond pomade increase the titratable acidity in Tarhana dough (Koca and Tarakçı, 1997).

3. 2 The color change was caused by addition of almond pulp to Tarhana

The L* values of Tarhana soups are shown in Table 2. The lowest L* value for the Tarhana sample was 47.68 for 30% almond pulp, and the highest L* value was determined as 59.52 for the control Tarhana sample. The effect of almond pulp additive on the L* value in Tarhana was found to be statistically significant ($p<0.05$). It was found that L* values decreased as the almond rate increased. Accordingly, it was concluded that the color of the soup darkened with the increase of almond pulp in due to the dark brownish color of the skins of almonds included in the pulp.

Table 2 displays a* values of Tarhana samples together with the variance analysis results. When the results are examined, it is understood that the effect of almond ratio on the a* value of tarhana is statistically significant ($p<0.05$). Tarhana soups a* values increase as the almond ratio increases. Accordingly, it was concluded that with the increase of almond pulp in tarhana, the redness of the soup color increased. Also, the effect of almond pulp on b* value of tarhana was statistically significant ($p<0.05$). The 10% almond pulp added tarhana has been found to increase the b* value whereas Tarhana with 5% almond pulp has been found to decrease b* value. In general, the almond ratio used in tarhana samples reduces the L* value while increasing a* and b* values. L*, a* and b* values were found generally compatible with the studies on tarhana (Erkan et al., 2006; Koca et al., 2006). However, the

difference in L*, a* and b * values compared to some tarhana studies is thought to be due to their different tarhana formulations and additives utilized in tarhana formulations (Aktaş et al., 2015; Bilgiçli et al., 2014; Ozboy-Ozbas, et al., 2010).

Table 2. The pH, titratable acidity and color values of Tarhana samples

Almond Ratio (%)	pH	Titratable acidy (%)	*L**	*a**	*b**
K	4.76±0.12g	0.58±0.09f	59.52±0.23a	-1.27±0.23e	29.93±0.43de
B5	4.85±0.12f	0.67±0.09e	58.73±0.13b	1.72±0.15d	28.92±0.45e
B10	4.93±0.11e	0.70±0.09d	56.78±0.24c	2.60±0.45c	30.24±0.57d
B15	4.97±0.11d	0.73±0.10c	54.17±0.39d	3.27±0.37c	32.30±0.41c
B20	5.02±0.11c	0.76±0.09b	50.80±0.30e	4.57±0.21b	40.05±0.03b
B25	5.08±0.13b	0.78±0.09a	49.98±0.07f	5.06±0.20ab	40.60±0.48b
B30	5.12±0.14a	0.79±0.09a	47.68±0.30g	5.63±0.24a	42.16±0.18a
MSE	0.000	0.000	0.067	0.079	0.163

MSE: mean squared error, Results were expressed as mean±standard deviation. These data are the average of three replicates. There is no statistically significant difference between the means marked with the same lower-case letters in the same column ($p>0.05$).

3.3 Functional properties change caused by addition of almond pulp to Tarhana

Viscosity is known as an important quality criterion (Erkan et al., 2006). Viscosity can be expressed as the resistance of fluid foods to flow (*Table 3*). It was reported that tarhana soup shows pseudoplastic behavior (Erbaş et al., 2005). It was determined that viscosity statistically decreases as almond additive increases in Tarhana ($p<0.05$). Decreasing concentration of polysaccharides has been reported to reduce aggregation (Ikegwu et al., 2009). It is possible to say that the amount of starch in the total mass decreases with the increase of almond pulp in Tarhana formulation. Based on this information, it is estimated that the mass reduction of starch, a type of polysaccharide, in the formulation results in reduced aggregation, which leads to a decrease in viscosity.

Water holding capacity is an important functional feature in viscous foods (Ertaş et al., 2015). The factors that determine the water retention capacity of tarhana are structural proteins and starch (Hayta et al., 2002). The effect of the almond ratio added to tarhana on water holding capacity was not statistically significant ($p>0.05$). The addition of almonds to the Tarhana formulation had no significant effect on the water holding capacity values. The reason for this is thought to be due to the almond's low starch content, which may affect the water holding capacity value.

Tarhana samples with the highest foaming capacity were found to have 0.970±02ml/ml in Tarhana samples containing 30% almond pulp (*Table 3*). Control tarhana samples had the lowest foaming capacity value of 0.01±0.01ml/ml. According to the results, as the almond pulp contribution increased in tarhana, the foaming capacity increased and the samples containing 30% almond pulp had the highest foaming capacity of any tarhana variety tested. There are significant differences between the control samples and almond added samples ($p<0.05$).

According to the results of the analysis, the effect of the almond pulp ratio on foam stability was found to be statistically significant ($p<0.05$). As the almond pulp ratio increases in tarhana, the foaming stability increases. Among these values, the tarhana variety with maximum foam stability value was for the 30% almond pulp samples and its value was calculated as 2.63 ± 0.15 min (*Table 4*). Tarhana variety with minimum foaming capacity is the control sample and its value is determined as 0.02±0.01 min. Anil et al. (2021) stated that the foam stability value of tarhana samples prepared with unbaked corn flour was about 2 times higher than the tarhana samples prepared with baked corn flour. In the study performed by Tarakçı et al. (2013), the foam stability value of wheat flour tarhana was determined as 10.00 min. The quince added tarhana produced by Gökmen (2009); control, raw, baked, and dried quince foam stability values were 0.35 min, 0.45 min, 1.28 min, and 1.41 min respectively.

Table 3. Viscosity, water retention capacity, foaming capacity and foam stability values of Tarhana samples

Almond Ratio (%)	Viscosity (cp)	Water Retention Capacity (ml/g)	Foaming capacity (ml/ml)	Foam stability (ml)
K	106.48±25.45a	0.73±0.01	0.01±0.01f	0.02±0.01g
B5	93.72±19.02ab	0.69±0.04	0.27±0.04e	0.42±0.03f
B10	80.45±16.04bc	0.71±0.03	0.59±0.05d	0.82±0.03e
B15	64.43±13.95cd	0.66±0.03	0.72±0.02c	1.30±0.08d
B20	56.75±14.18de	0.63±0.05	0.77±0.03c	1.68±0.05c
B25	40.31±10.86ef	0.63±0.06	0.88±0.04b	1.93±0.06b
B30	27.60±7.00.88f	0.72±0.11	0.97±0.02a	2.63±0.15a
MSE	11.300	0.003	0.001	0.005

MSE: mean squared error, Results were expressed as mean±standard deviation. These data are the average of three replicates. There is no statistically significant difference between the means marked with the same lower-case letters in the same column ($p>0.05$).

3. 4 Ash, fat, protein, total phenolic and antioxidant capacity values of Tarhana

Proteins are used in the production of foam in the food industry. It is known that wheat and soy proteins, which have different foam-forming properties, are among the proteins with the highest foaming property (Kurek et al., 2022). Many factors, such as protein type, protein content, fat content, controlling power, and pH, play a critical role in foaming capacity and stability. Multiple comparison test results of protein amount according to almond pulp ratio are given in Table 4. Among these values, tarhana varieties having maximum protein amount of tarhana samples containing 30% almond pulp and mean value 16.11±0.03 g was harvested as sample. The tarhana variety with the minimum amount of protein is control tarhana and its value is 12.28±0.12g. It is seen that the amount of protein increases significantly as the almond pulp ratio increases in Tarhana groups. It is understood that the high protein content of almond fruit is reflected in tarhana samples with almond pulp additives.

Phenolic compounds contribute to the aroma and taste of many foods of plant origin. The contribution of the compounds to the aroma is mainly due to the presence of volatile phenols (Rodriguez et al., 2009). Total phenolic substance determination results are given in *Table 4*. In result of the measurements, the lowest amount of phenolic substance is 1598 mg GAE/kg. The highest phenolic content was found as 2376 mg GAE/kg sample for 30% almond pulp tarhana samples.

Table 4. Ash, fat, protein, total fenolic and antioxidant capacity values of Tarhana samples

Almond Ratio (%)	Ash (%)	Fat (%)	Protein (%)	TFMM (mgGAE/100g)	Antioxidant (mgTroloxE/kg)
K	1.21±0.01e	2.19±0.10g	12.28±0.12g	1640±0.01g	150±0.00f
B5	1.41±0.02d	4.28±0.27f	13.02±0.02f	1850±0.01f	240±0.00e
B10	1.49±0.01c	5.97±0.11e	13.85±0.02e	2020±0.01e	290±0.01d
B15	1.54±0.01c	7.75±0.10d	14.61±0.04d	2160±0.02d	350±0.00c
B20	1.59±0.01b	9.02±0.16c	15.17±0.08c	2240±0.01c	390±0.01b
B25	1.63±0.03a	10.29±0.11b	15.61±0.05b	2330±0.01b	420±0.01a
B30	1.65±0.01a	11.52±0.08a	16.11±0.03a	2360±0.01a	430±0.00a
MSE	0.000	0.022	0.009	0.000	0.000

MSE: mean squared error, Results were expressed as mean±standard deviation. These data are the average of three replicates. There is no statistically significant difference between the means marked with the same lower-case letters in the same column ($p>0.05$).

Table 4 shows the results of multiple comparison tests on total phenolic substance based on almond pulp ratio. Tarhana variety with the highest phenolic content contains 30% almond pulp and its value is 2360±0.01mgGAE/kg sample. Tarhana sample with the lowest amount of phenolic substance was observed as a control sample (1640 mg GAE/kg). When the results were examined, it was found that almond fruit significantly increased the total phenolic content of tarhana ($p<0.05$). It is thought that almond kernels have a high total amount of phenol and tocopherol to achieve this result (Kornsteiner *et al.*, 2006). The results of the analysis of variance of antioxidant activity in Tarhana samples are shown in Table 4. When the results were examined, the effect of almond ratio on antioxidant activity was found to be statistically significant ($p<0.05$). Among the values, tarhana samples containing 30% almond pulp have the highest antioxidant activity; the value is 430±0.00 mg TroloxE/kg. Tarhana variety with the lowest antioxidant activity was the control group; the value is approximately 150mg TroloxE/kg

sample. When the results were examined, it was understood that the antioxidant amount of the samples increased significantly due to the almond pulp contribution. The antioxidant content of the tarhana group, which had the highest almond pulp addition, was found to be approximately three times that of the control group ($p<0.05$).

3.5 Sensory properties of Tarhana samples

Panelists reported a significant color difference between the control and almond pulp tarhana samples, and they preferred the almond pulp tarhana samples to the control tarhana (*Table 5*). In the control tarhana samples without almonds, it is estimated that the pepper, tomato paste, and mint in the formulation do not contribute much to the color attractiveness. In this case, it is thought that the almond pulp added to the tarhana improves the soup's appeal by changing the color of the product. Tarhana soups with 5% almond pulp were the most appreciated in terms of color. This is thought to be related to the fact that it contains almond additive at the rate closest to the usual tarhana color. It is estimated that other tarhana soups with almond pulp additions are therefore less appreciated as the color darkens as the almond ratio increases.

Table 5. Sensory properties of Tarhana samples

Almond Ratio (%)	Color and appearance	Smell	Consistency	Taste and Flavor	General Acceptability
K	6.10±1.45b	6.70±1.25	7.90±1.10	6.80±1.81	6.70±1.34
B5	8.30±0.82a	7.60±1.51	8.30±1.06	7.80±1.55	7.80±1.32
B10	8.10±0.74a	7.60±1.51	8.10±0.32	7.70±1.34	7.70±1.06
B15	8.20±1.32a	7.90±1.10	7.90±1.29	7.80±1.14	8.00±0.94
B20	7.90±0.99a	7.60±1.27	7.90±1.10	7.70±1.57	7.70±1.16
B25	7.50±0.85ab	7.60±1.17	7.40±1.08	8.00±1.05	7.60±0.97
B30	8.00±1.05a	7.60±1.35	7.50±1.18	8.00±1.56	7.80±1.55
MSE	1.125	1.730	1.121	2.111	1.459

MSE: mean squared error, Results were expressed as mean±standard deviation. These data are the average of three replicates. There is no statistically significant difference between the means marked with the same lower-case letters in the same column ($p>0.05$).

Tarhana sample, which has the highest odor score, is a sample containing 15% almond pulp and its average value is; 7.9±1.10; and the lowest odor group was the tarhana control group with a mean value of 6.7±1.25. There was no statistically significant difference between soup types ($p>0.05$). The most popular soup in terms of smell was found to be tarhana with almond pulp added 15%.

The Tarhana sample with the highest consistency score is 5% almond pulp soup, with an average value of 8.30±1.06; the group with the lowest consistency score is 25% almond pulp soups and the average value is 7.40±1.08. There was no statistically significant difference between the soup types in terms of consistency ($p>0.05$). Tarhana soups with 5% almond pulp added have the most popular consistency. Considering that the cooking time of tarhana samples is 10 minutes, it is estimated that this time is the most appropriate time for soups with 5% almond pulp added among all groups.

In *Table 5*, values of taste-aroma analysis among tarhana samples are given. Among these values, tarhana sample with the highest taste-aroma score is a tarhana sample containing 30% almond pulp, with an average value of 8.00 ±1.56 the control group had the lowest taste-aroma score, with a mean value of 6.80±1.81. There was no significant difference in taste-aroma between soup types ($p>0.05$). When some studies were examined, various flours such as barley flour, quinoa flour, and corn flour were used instead of wheat flour, and these products were scored low in terms of general acceptability (Erkan et al., 2006; Üçok et al., 2019). However, wheat flour was used in this study and no other flour was substituted in the formulation. Therefore, it is estimated that the almond has a position effect on the increase of general acceptability.

4. Conclusion

It was determined that the amount of protein, inorganic matter, and fat increased significantly with the increase in the use of almond pulp in tarhana. It has been determined that the high amount of protein and fat content and inorganic substance composition of almond fruit are reflected in the tarhana samples, increasing the nutritional quality significantly.

It was determined that the total phenolic substance and antioxidant activity values increased with the increase in the amount of almond pulp additive in the tarhana samples, and it was determined that the strong antioxidant amount in the almond composition was reflected in the tarhana samples. Furthermore, it is estimated that spices such as red pepper, mint, and onion in the formulation have a positive effect on the antioxidant activity of tarhana.

When the sensory properties of tarhana soups were examined, the almond pulp-added tarhana samples were more appreciated than the control samples in terms of color and odor. It has been determined that tarhana with high almond content in terms of taste and aroma is preferred. It is thought that the aromatic compounds in almonds and the oil have a positive effect on the taste and aroma of soups. When the soups were evaluated overall, it was determined that the soups with almond pulp were preferred over the control group soups.

It is thought that the use of fruit or fruits with high nutritional power and antioxidant capacity as additives in the production of tarhana in the future, which can positively affect the taste and appearance, will enrich the tarhana. Thus, it is thought that tarhana will not only expand the domestic production volume but also make a significant contribution to our country's economy.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Kilis İli Tarım Topraklarının Beslenme Durumunun İncelenmesi

Investigation of Nutritional Status in Kilis Province Agricultural Soils

Ahmet KILIÇ[1*], Meryem KUZUCU[2], İbrahim Samet GÖKÇEN[3]

Öz

Bu çalışmada, Kilis ili merkez ve ilçe köylerinde yer alan tarım topraklarının verimlilik düzeyi incelenmiştir. Bu amaçla toprağın 0-30cm derinliğinden alınan örneklerde bünye, pH, EC, $CaCO_3$, organik madde, fosfor ve potasyum analizleri yapılmıştır. Toprağın bazı fiziksel ve kimyasal analizlerinin belirlenmesi için alınan 40 adet toprak örneği verimlilik bakımından değerlendirilmiştir. Elde edilen sonuçlara göre, Kilis ili tarım topraklarının hafif alkali reaksiyonlu olduğu, %55'inin killi, %30'unun killi tınlı, %15'inin ise tın tekstüre sahip olduğu, toprakların organik madde içeriği bakımından %12.5'i çok az, %50' si az, %32.5''i orta düzeyde ve %5'i yeterli sınıfına dâhil olmuştur. Kilis ili tarım toprakları genel olarak tuzsuz, %2.5'inin kireçli, %67.5'inin orta kireçli, %22.5'inin fazla kireçli ve %7.5'inin çok fazla kireçli olduğu belirlenmiştir. Tarım topraklarında yüksek kireç içeriğinin, fosfor gibi bazı önemli besin elementlerinin alınabilirliğini sınırlandırdığı ortaya çıkmıştır. Kilis ili tarım toprakları yeterli düzeyde potasyuma sahip olup, %24'ünün fosfor içeriğinin çok az, %14'ünün az ve %2'sinin orta sınıfa dâhil olduğu belirlenmiştir. Sürekli ve verimli bir bitkisel üretim için topraktan kaldırılan besin maddesinin tekrar toprağa ilave edilmesi gerekmektedir. Kilis ili üreticileri yüksek kireç ve düşük organik madde içeren bu topraklarda, gübreleme yapmadan üretim gerçekleştirmektedir. Toprakta var olan besin maddesi yıllar itibariyle bitkiler tarafından tüketilmektedir. Bu süreç neticesinde toprağın verimliliği azalmakta ve ürün verimi düşmektedir. İlimiz üreticileri, ekonomik nedenlerle mineral gübre kullanımını sınırlı tutmaktadırlar. Yabancı ot probleminden dolayı çiftlik gübresi de tercih edilmemektedir. Kilis ilinde genellikle tarla bitkileri ve sebze yetiştirilen tarım topraklarında beslenme sorunlarının bulunduğu, bitkilerin ihtiyaç duyduğu dönemlerde, toprak analizleri sonucuna göre, gereken miktarda gübre uygulanması gerekmektedir. Ayrıca organik gübre kullanımına önem verilmesi ve böylece toprağın sürdürülebilir verimliliği sağlanmalıdır.

Anahtar Kelimeler: Toprak, Tarım, Verimlilik, Besin elementi, Kilis.

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Abstract

In this study, the productivity level of agricultural lands in the central and district villages of Kilis province was investigated. For this purpose, texture, pH, EC, $CaCO_3$, organic matter, phosphorus and potassium analyzes were made in the samples taken from 0-30 cm depth of the soil. To determine some physical and chemical analyzes of the soil, 40 soil samples were evaluated in terms of productivity. According to the findings, the agricultural soils of Kilis province have a slightly alkaline reaction, 55% are clayey, 30% are clay loam, 15% have loam texture, 12.5% of the soils are very low in terms of organic matter content. 50% were in the low, 32.5% moderate and 5% good class. It has been determined that the agricultural soils of Kilis province are generally unsalted, 2.5% lime, 67.5% moderately lime, 22.5% highly lime and 7.5% too high lime. It has been revealed that high lime content in agricultural soils limits the availability of some important nutrients such as phosphorus. Agricultural soils in Kilis province have sufficient potassium, 24% of them have very low phosphorus content, 14% are low and 2% are in the middle class. For a continuous and efficient plant production, the nutrient removed from the soil must be added to the soil again. Producers Kilis province produce in these soils with high lime and low organic matter without fertilization. Nutrients in the soil are consumed by plants over the years. As a result of this process, the fertility of the soil decreases and the product yield decreases. Producers of our province limit the use of mineral fertilizers for economic reasons. Due to the weed problem, farm manure is not preferred. According to the results of the soil analysis, the required amount of fertilizer should be applied during the periods when there are nutritional problems in the agricultural lands where field crops and vegetables are grown in Kilis and when the plants need it. In addition, importance should be given to the use of organic fertilizers and thus sustainable fertility of the soil should be ensured.

Keywords: Soil, Agriculture, Productivity, Nutrient element, Kilis.

1. Giriş

Kilis ilinde tarım önemli bir sektör konumundadır. Yüzölçümü 1 milyon 412 bin dekar olan ilde, toplam tarım alanı 1milyon 17bin dekardır. Çiftçi kayıt sistemine kayıtlı 9 bin üreticisi bulunmaktadır. Tarımsal üretimde dış pazara ulaşım olanakları sınırlıdır. Kilis ili Akdeniz iklimi ile karasal iklimin kesiştiği bölgede bulunmaktadır, bu iklimlerin sahip olduğu özellikler ilde hâkim durumdadır. Sıcak ve kuru hava bazen yerini serin ve nemli havaya bırakarak, farklı klimatolojik özellikler göstermektedir. Bu nedenlerle Kilis ili tarımsal potansiyeli ve ürün çeşitliliği yönünden zengin bir ilimizdir. İlin sahip olduğu iklim ve toprak yapısı tarımsal üretimde çeşitliliği artırmaktadır. Kilis ilinde dünya çapında önem kazanmış ürün çeşitlerinin yanı sıra farklı ekolojilere adapte olmuş ürünler de yetişebilmektedir (Anonim, 2022).

Kilis ilinde tarım ürünlerinin tarım arazilerine dağılımı ve bu alanlarda gerçekleştirilen üretim miktarları *Tablo 1'* de verilmiştir. Kilis ili tarımsal arazi varlığı yönünden geniş üretim alanlarına sahiptir. Bu arazi varlığına rağmen üretim miktarları istenilen seviyeye ulaşmamıştır.

Tablo.1. Tarım ürünlerinin tarım arazilerine dağılımı ve üretim miktarı

Table.1. Distribution of agricultural products on agricultural lands and production amount

	2002		2020		2021	
Ürün	**Üretim Alanı (ha)**	**Üretim Miktarı (ton)**	**Üretim Alanı (ha)**	**Üretim Miktarı (ton)**	**Üretim Alanı (ha)**	**Üretim Miktarı (ton)**
Meyve	351.530	71.247	552.666	163.884	543.167	130.417
Sebze	132.520	224.529	49.182	125.716	53.615	139.600
Tarla	520.270	101.317	360.010	89.547	374.107	71.591

(TÜİK, 2021)

Tablo.2. Kilis ili 2021 yılı tarla ve bahçe ürünleri üretim verileri

Table.2. Kilis province 2021 field and garden products production data

Ürün Adı	**Türkiye Üretimi (ton)**	**İl Üretimi (ton)**	**Türkiye Üretimi İçindeki Payı (%)**
Üzüm	3.670.000	51.685	1.41
Kırmızıbiber	284.694	46.465	16.32
Zeytin	1.738.680	24.000	1.38
Domates	13.095.258	22.420	0.2
Buğday	17.650.000	49.943	0.28
Arpa	5.750.000	12.412	0.22
Mercimek (Kırmızı)	228.000	2.520	1.11

(TÜİK, 2021)

Kilis ilinde yetiştirilen bazı tarla bitkileri ve sebzelerin Türkiye üretimi içindeki payı istenilen seviyelere ulaşmamış olduğu görülmektedir (*Tablo.2*). Tarımsal üretim kışlık tarla ürünlerinde kuru tarım olarak gerçekleştirilirken, ilimizde sebze üretimi çoğunlukla damla sulama ile yapılmaktadır. Manisa-Akhisar'da biber yetiştiriciliği yapılan toprakların organik madde, toplam azot, alınabilir fosfor, demir ve mangan içeriklerinin yetersiz olduğu, organik gübrelerin yanında azot, fosfor, demir ve manganlı gübreleri kullanmaları gerektiği bildirilmiştir (Erdoğan Bayram ve ark., 2019). Özellikle meyvecilikte kuru üretimin yanında bakım ve gübreleme işlemleri eksik ve geleneksel uygulamalara bağlı kalınarak yürütülmektedir. Bu nedenle tarım toprakları zamanla verimini kaybetmekte ve üretim azalmaktadır. Tarımsal üretim yapılan toprakların mevcut verimlilik düzeylerinin korunması ve iyileştirilmesi için çiftçiler gerekli önlemi almalılardır (Başar, 2001). Salihli yöresi bağlarının, organik madde içeriğinin düşük olduğu ve organik gübrelemeye önem verilerek, toprak organik maddesi artırılmalıdır (Yağmur ve Okur, 2017).

Tarım arazilerinde sürdürülebilirliği sağlamak ve devamlı ürün verimi için toprak verimliliğine gereken önemi verilmelidir. Aksi takdirde toprağın verimliliği azalmakta ve sürekli bir verim düşüklüğü yaşanabilmektedir (Günal, 2008). Toprağın verimliliğinin devamı için gübreleme en önemli kültürel tedbirlerden birisidir. Tarım arazilerinin beslenme problemleri belirlenmeli ve uygun çözüm önerileri geliştirilmelidir (Sağlam, 2008). Toprak tekstürü toprağın önemli bir fiziksel özelliği olup verimlilik için önem arz etmektedir. Toprakların porozitesi, hacim ağırlığı, penetrasyon direnci, besin ve su tutma kapasitesi ve hidrolik iletkenlik gibi toprağın birçok özelliğini etkilediği bilinmektedir (Erşahin, 2001).

Bitki besleme ve gübreleme, tarımsal üretimde istenilen verim düzeyine ulaşabilmek için toprağa besin maddelerinin ilave edilmesi olarak tanımlanmaktadır. Tarım topraklarında verimliliği arttırmanın en etkili yolu gübreleme yapmaktır. Besin maddeleri toprağa veya bitkiye uygulanabilir. Bu şekilde toprakların fiziksel kimyasal ve biyolojik yapısı iyileştirilebilmektedir. Gübreleme yapılmadan üretime devam edilirse topraklar verimliliğini kaybedebilirler. Toprak analizleri ile toprağın besin içeriği belirlenebilir ve bu şekilde doğru zaman ve miktarda gübreleme yapılmalıdır. Bu gübreleme ancak toprak analizleri sonucuna göre yapılmalıdır ve böylece toprak verimliliği artırılmış olur (Sağlam, 2012).

Kilis ilinde tarımsal üretim genellikle kuru koşullarda yapılmaktadır. Bazı dönemlerde yağış azlığı ile tarım ürünleri için ihtiyaç duyulan su temin edilememektedir. Su azlığının yanında gübrelemeye de gereken önem verilmemektedir. Bu sebeplerden dolayı ürün veriminde azalmalar yaşanmaktadır. Tarım arazileri sürekli işlenmekte ve içeriğindeki besin maddesi yıllar itibariyle azalmaya devam etmektedir. Toprağın verimliliğini artıracak, gübreleme sulama, nadas, ekim nöbeti, azaltılmış toprak işleme gibi toprağı koruyucu faaliyetlerin de yetersizliği ile topraklar verimliliğini yitirmektedir. Bu çalışmada, Kilis ilinin tarım topraklarının verimlilik durumlarının belirlenmesi, bazı fiziksel ve kimyasal özelliklerinin incelenmesi, doğal bir kaynak olan toprağın bilinçli kullanılması, tarım arazilerinde verimliliğin artırılması için toprak analizlerinin yapılması ve analiz sonuçlarına göre tarım topraklarının verimlilik durumunu incelemek için yapılmıştır.

2. Materyal ve Metot

2.1. Materyal

Kilis ili ve ilçe köylerinde, kuru ve sulu koşullarda yetiştirilen arpa, buğday, mercimek, nohut, fiğ, biber, karpuz gibi tarımsal ürünlerin yetiştirildiği, tarım topraklarının 0-30cm derinliğinden alınan toprak örnekleri bu çalışmanın materyalidir. Laboratuvara getirilen toprak örnekleri hava kurusu hale getirildikten sonra 2 mm'lik elekten geçirilerek analize hazır hale getirilmiştir. Bu çalışmada, 2020-2021 yılları içerisinde, Kilis ilini tamamen temsil edebilecek bölgelerden alınmış 40 adet toprak örneği kullanılmıştır (*Şekil.1*).

2.2. Metot

Toprak örneklerinde toprak bünyesi Bouyoucos hidrometre yöntemiyle (Bouyoucos, 1951). Organik madde miktarı (%): (Walkley and Black, 1934) dikromat oksidasyon yöntemine göre, Kalsiyum karbonat (%): Scheiber kalsimetresi ile (McLean, 1982), alınabilir fosfor (P_2O_5) 0.5 N $NaHCO_3$ ile (Tüzüner, 1990; Olsen ve Sommers, 1982) alınabilir potasyum (K_2O): 1.0 N Amonyum asetat (pH 7.0) kullanılarak ekstrakta geçmiş potasyum fleymfotometrede okunarak (Tüzüner, 1990), (Chapman ve Pratt,1961) toprak reaksiyonu, saturasyon çamuru ile pH metre ile toprak reaksiyonu ölçülmüş, yine saturasyon çamurundan toplam eriyebilir tuz miktarı, EC metre (Richards, 1954), (Tüzüner, 1990) ile belirlenmiştir.

Toprak örneklerinin alındığı noktalar Kilis ili ve ilçelerini genel anlamıyla temsil edecek nitelikte dağılıma sahiptir (*Şekil.1*). Değerlendirmeye alınan 40 adet toprak örneğinin alındığı ilçe, köy ve örneklenen noktanın koordinatları *Tablo 3*'te verilmiştir.

Tablo.3 Toprak örneği alınan köyler ve koordinatları

Table.3 Villages from which soil samples were taken and their coordinates

Toprak no	İl	İlçe	Köy	Enlem-Boylam(N-E) Koordinatları
1	Kilis	Elbeyli	Akçaağıl	36°47'38.3"N 37°26'18.9"E
2	Kilis	Merkez	Güvenli	36°48'57.3"N 37°16'32.1"E
3	Kilis	Merkez	Karamelik	36°47'25.9"N 37°15'03.6"E
4	Kilis	Musabeyli	Balıklı	36°54'21.3"N 36°55'56.8"E
5	Kilis	Merkez	Beşenli	36°47'16.0"N 37°03'14.9"E
6	Kilis	Elbeyli	Havuzluçam	36°39'52.4"N 37°24'00.5"E
7	Kilis	Polateli	Bağarası	36°49'51.5"N 37°03'24.4"E
8	Kilis	Polateli	Polatbey	36°48'14.3"N 37°11'23.0"E
9	Kilis	Merkez	Saatli	36°47'12.2"N 36°52'20.8"E
10	Kilis	Merkez	Uzunlu	36°46'06.8"N 37°13'05.7"E
11	Kilis	Polateli	Yeniyapan	36°51'54.4"N 37°13'33.6"E
12	Kilis	Merkez	Hacipoğlu	36°48'01.2"N 36°57'24.6"E
13	Kilis	Merkez	Duruca	36°45'18.1"N 37°01'46.7"E
14	Kilis	Elbeyli	Alahan	36°39'52.9"N 37°26'17.3"E
15	Kilis	Merkez	Çerçili	36°48'32.6"N 36°46'26.1"E
16	Kilis	Merkez	Tahtalı	36°48'32.6"N 36°46'26.1"E
17	Kilis	Merkez	Gümüşsuyu	36°48'36.4"N 37°17'27.5"E
18	Kilis	Polateli	Ürünlü	36°50'31.7"N 37°05'49.0"E
19	Kilis	Polateli	Dümbüllü	36°48'59.1"N 37°01'38.4"E
20	Kilis	Merkez	Tanburalı	36°45'52.5"N 37°06'28.0"E
21	Kilis	Merkez	Çörten	36°46'25.0"N 37°17'47.8"E
22	Kilis	Merkez	Yavuzlu	36°41'44.8"N 37°16'20.4"E
23	Kilis	Musabeyli	Çayıraltı	36°56'24.8"N 36°59'28.8"E
24	Kilis	Elbeyli	Güvendik	36°41'34.5"N 37°22'30.4"E
25	Kilis	Merkez	Mağaracık	36°48'08.1"N 36°50'44.6"E
26	Kilis	Merkez	Acar	36°44'39.3"N 37°11'37.8"E
27	Kilis	Merkez	İnanlı	36°39'58.1"N 37°09'54.7"E
28	Kilis	Musabeyli	Aşağıbademli	36°55'52.1"N 36°58'00.1"E
29	Kilis	Merkez	Küplüce	36°45'10.5"N 37°14'35.8"E
30	Kilis	Polateli	Belenözü	36°52'40.1"N 37°04'21.2"E
31	Kilis	Elbeyli	Çıldıroba	36°38'55.9"N 37°24'22.9"E
32	Kilis	Musabeyli	Kürtüncük	36°56'11.9"N 36°58'16.9"E
33	Kilis	Merkez	Bulamaçlı	36°48'59.9"N 36°48'50.9"E
34	Kilis	Musabeyli	Dorucak	36°51'16.8"N 36°53'07.7"E
35	Kilis	Merkez	Çukuroba	36°45'53.2"N 37°08'36.0"E
36	Kilis	Merkez	Akçabağlar	36°40'17.4"N 37°03'48.6"E
37	Kilis	Musabeyli	Bozkaya	37°00'24.1"N 36°58'26.4"E
38	Kilis	Merkez	Hisarköy	36°49'51.9"N 36°45'52.8"E
39	Kilis	Musabeyli	Hüseyinoğlu	36°55'41.2"N 36°55'41.2"E
40	Kilis	Elbeyli	Yağız	36°40'51.1"N 37°21'49.7"E

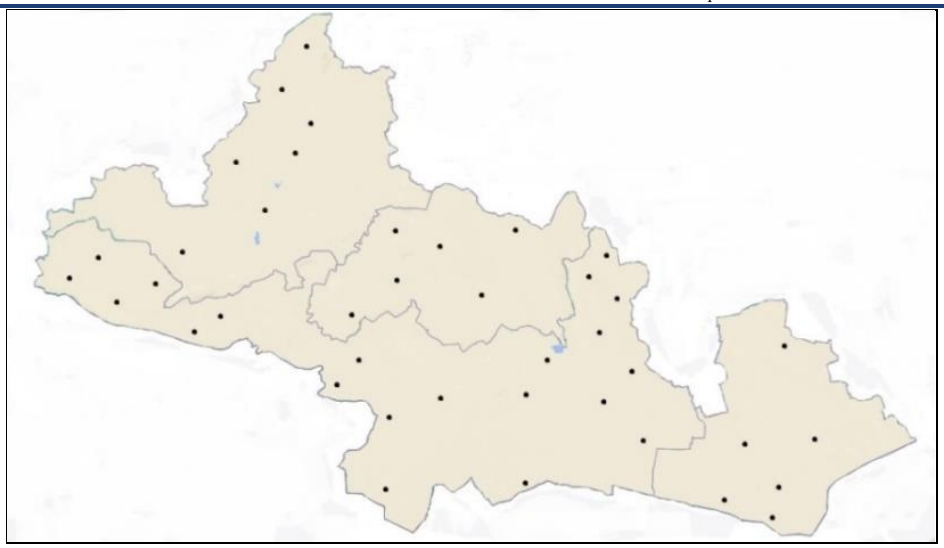

Figure.1. Soil samples taken from Kilis province

Şekil.1 Kilis ili toprak örneklerinin alındığı noktalar

3. Araştırma Sonuçları ve Tartışma

Kilis ilinde tarımsal üretim yapılan toprakların bazı fiziksel ve kimyasal özelliklerine ait değerler *Tablo 3*'te verilmiştir. Kilis ilini temsilen merkez ve ilçe köylerden alınan toprak örneklerinin verimlilik durumu belirlenmiştir. Toprakların verimlilik durumu belirlenirken (Ülgen ve Yurtsever, 1995)'e göre kabul edilen sınır değerler dikkate alınarak değerlendirilmiştir (*Tablo.4*).

Tablo.4 Toprak verimliliğinde kabul edilen sınır değerler

Table.4 Accepted limit values in soil fertility

Toprak Analizi	**Kabul Edilen Sınır Değerleri**					
pH	<4.5 ise Kuvvetli asit	4.5-5.5 ise Orta Asit	5.5-6.5 ise Hafif Asit	6.5-7.5 ise Nötr	7.5-8.5 ise Hafif Alkali	>8.5 ise Kuvvetli Alkali
Kireç (%)	0-1 ise Az kireçli	1-5 ise Kireçli	5-15 ise Orta Kireçli	15-25 ise Fazla Kireçli	>25 ise Çok fazla Kireçli	
Tekstür (%Saturasyon)	0-30 ise Kum	30-50 ise Tın	50- 70 ise Killi Tın	70-110 ise Kil	>110 ise Ağır Kil	
Tuz (%)	0-0.15 ise Tuzsuz	0.15-0.35 ise Hafif Tuzlu	0.35-0.65 ise Orta Tuzlu	>0.65 ise Çok Tuzlu		
Organik Madde (%)	0-1 ise Çok az	1-2 ise Az	2-3 ise Orta	3-4 ise İyi	>4 ise Yüksek	
Fosfor (kg/da)	< 3 ise Çok az	3-6 ise Az	6-9 ise Orta	9-12 ise Yüksek	>12 Çok Yüksek	
Potasyum (kg/da)	< 20 ise Az	20-30 ise Orta	30-40 ise Yeterli	>40 ise Fazla		

Kaynak: Ülgen ve Yurtsever (1995)

Genellikle tarla bitkileri ve sebze üretiminin yoğun olarak yapıldığı bu örnekleme yapılan köylerde toprakların hafif alkali reaksiyona sahip olduğu belirlenmiştir. Tarım topraklarının pH değerleri 6.73 ile 8.11 arasında değişmektedir. Kireç içeriği ise % 4.462 ile % 56.146 arasında değişmekle birlikte ortalama olarak orta kireçli sınıfında yer almıştır.

Toprakların fosfor içeriği 0.95 kg/da^{-1} ile 10.66 kg/da^{-1} arasında değişmekle birlikte, genel olarak az olduğu, potasyum içeriğinin ise; 25.42 kg/da^{-1} ile 167.15 kg/da^{-1} arasında olup yeterli düzeyde ve tuzsuz topraklar olduğu

belirlenmiştir. Organik madde içeriği yönünden bu tarım toprakları, % 0.62-% 3.15 arasında elde edilen değerlerle, az düzeyde organik madde içeren topraklar sınıfına dâhil olmuştur. Kilis ili tarım topraklarının killi, killi tın ve tın bünyeye sahip olduğu belirlenmiştir (*Tablo 5*).

Tablo.5 Kilis ili tarım topraklarının bazı fiziksel ve kimyasal analizleri

Table.5 Some physical and chemical analysis of agricultural soils in Kilis province

Toprak örneği No	Köy	pH	Tekstür	Tuz (%)	Kireç (%)	Organik Madde (%)	Fosfor (kg/da^{-1})	Potasyum (kg/da^{-1})
1	Akçaağıl	7.14	Killi	0.0581	56.146	1.73	10.66	80.97
2	Güvenli	7.18	Killi	0.0439	10.884	1.92	5.03	72.56
3	Karamelik	7.62	Killi	0.0474	16.401	2.05	5.08	67.50
4	Balıklı	7.65	Killi	0.0370	11.057	3.15	4.69	50.00
5	Beşenli	7.75	Killi	0.0660	7.474	3.10	5.03	87.50
6	Havuzluçam	7.71	Killi tın	0.0427	4.462	1.18	1.24	86.45
7	Bağarası	7.73	Killi tın	0.0417	8.607	1.47	2.18	67.20
8	Polatbey	7.82	Killi tın	0.0428	8.036	1.40	1.12	65.18
9	Saatli	8.11	Killi tın	0.0382	12.817	2.04	2.14	70.32
10	Uzunlu	8.20	Killi tın	0.0368	18.306	1.17	5.32	75.25
11	Yeniyapan	7.87	Tınlı	00272	24.959	2.42	5.08	88.66
12	Hacipoğlu	7.98	Tınlı	0.0155	18.220	1.38	4.12	85.24
13	Duruca	8.02	Tınlı	0.0207	7.095	1.21	1.24	40.15
14	Alahan	6.97	Killi	0.0332	9.833	2.40	2.40	32.78
15	Çerçili	7.07	Killi	0.0631	14.628	0.99	4.86	93.61
16	Tahtalı	7.15	Killi	0.0770	19.551	2.10	5.95	103.50
17	Gümüşsuyu	7.36	Killi	0.0407	18.803	1.09	5.13	62.35
18	Ürünlü	7.52	Killi	0.0489	11.848	2.17	2.03	67.45
19	Dümbüllü	7.62	Killi	0.0474	8.401	1.47	1.03	71.28
20	Tanburalı	7.12	Killi	0.0636	6.861	2.10	5.20	95.17
21	Çörten	7.70	Killi	0.0588	28.142	1.21	8.07	99.45
22	Yavuzlu	7.74	Killi	0.0517	5.428	0.62	2.06	27.67
23	Çayıraltı	7.76	Killi	0.0651	15.276	2.60	1.40	57.22
24	Güvendik	7.80	Killi	0.0480	9.849	1.84	2.12	71.42
25	Mağaracık	7.46	Killi tın	0.0405	14.125	2.47	3.10	67.85
26	Acar	7.75	Killi tın	0.0445	16.227	1.75	1.73	95.62
27	İnanlı	7.76	Killi tın	0.0410	5.223	1.12	2.03	64.23
28	Aşağıbademli	7.84	Killi tın	0.0329	6.188	1.47	2.08	86.52
29	Küplüce	7.85	Killi	0.0502	5.706	2.16	2.13	149.25
30	Belenözü	7.85	Killi	0.0779	8.438	1.10	1.26	67.40
31	Çıldıroba	7.93	Killi	0.0599	6.429	0.96	1.81	63.56
32	Kürtüncük	7.84	Killi	0.0508	12.677	1.14	4.06	113.41
33	Bulamaçlı	7.88	Killi tın	0.0342	9.418	1.66	1.09	101.25
34	Dorucak	7.92	Killi tın	0.0434	12.429	0.98	2.14	72.18
35	Çukuroba	7.95	Killi tın	0.0428	5.625	1.13	0.95	67.52
36	Akçabağlar	7.85	Tınlı	0.0185	17.818	2.07	1.71	70.81
37	Bozkaya	6.73	Tınlı	0.0193	53.124	1.55	2.17	68.12
38	Hisarköy	6.76	Tınlı	0.0274	10.394	2.10	3.32	71.66
39	Hüseyinoğlu	7.48	Killi	0.0557	13.285	2.14	2.41	167.15
40	Yağız	7.52	Killi	0.0412	12.512	0.86	1.27	25.42
Min.		**6.73**		**0.0155**	**4.462**	**0.62**	**0.95**	**25.42**
Max.		**8.11**		**0.0779**	**56.146**	**3.15**	**10.66**	**167.15**
Ortalama		**7.62**		**0.039**	**14.067**	**1.68**	**3.16**	**76.7**

Toprağın organik madde içeriği, su tutma kapasitesini, havalanmasını, infiltrasyonu, sıcaklığı ve strüktürü gibi fiziksel özelliklerinin iyileşmesine katkıda bulunarak toprağın muhafazası üzerine etkili olmaktadır (Anonim, 1968). Kilis ili toprakları organik madde içeriği ortalama %1.68 olup az olarak belirlenmiştir (*Tablo. 5*).

Tarım topraklarının yarısının organik maddesi az düzeyde, sadece % 5'lik kısmı organik madde içeriği yönünden iyi sınıfına dâhil olurken, % 12.5'i çok az olarak belirlenmiştir. Organik madde aynı zamanda toprağın kimyasal özelliklerini de iyileştirmektedir. Katyon değişimi, besin elementi içeriği ve besinlerin yarayışlılığı üzerine katkıda bulunmaktadır. Özellikle çiftlik gübresi uygulamaları toprağın organik maddesini, fosfor ve potasyum içeriğini artırmaktadır (Magdoff ve Van Es, 2000; İrget ve Cengiz, 2018). Organik gübre kullanımı insan sağlığını koruma ve bilinçli tarımsal üretim için günümüzde önem kazanmaktadır. Ayrıca tarım ürünlerinin kalitesinin bozulmasını da önlemektedir. Başta leonardit ve çiftlik gübresi olmak üzere çeşitli organik gübreler, kimyasal gübrelerin toprak ve su kaynaklarında yarattığı olumsuzlukları giderebilmektedirler (Adiloğlu ve Adiloğlu, 2017).

Kilis ili tarım topraklarının ortalama pH'sı 7.62 olup hafif alkali sınıfında yer almıştır (*Tablo.5*). Alkali toprakların pH'sının düşürülmesi için sülfat içeren gübreler başarılı olmaktadır. Organik maddenin yetersiz olduğu topraklarda organik gübreler fayda sağlamaktadır. Organik gübrelerden ahır gübresi, yeşil gübreleme ve çeşitli kompost uygulamaları toprağa organik madde ilavesi için kullanılabilecek en iyi uygulamalardır (Kacar ve Katkat, 2007). Kireçli toprakların pH'sının hafif alkali düzeyde olduğu birçok çalışma sonucunda bildirilmiştir (Doran ve ark., 2008).

Kilis ili tarım toprakları Soil Survey Staff, (1951) ve Ülgen ve Yurtsever, (1995)'in belirlediği sınır değerine göre tuzsuz sınıfında yer almıştır (*Tablo.4*). Toprak tuzluluğu toprağın verimliliğini büyük ölçüde etkilemektedir. Toprak çözeltisinin ozmotik potansiyelini değiştirmekte ve ayrıca değişebilir sodyum içeriğini artırmaktadır. Tuzluluk problemi zaman içerisinde topraklarda fiziksel özellikleri etkileyerek verimde azalmalara neden olmaktadır (Richards ve ark., 1954).

Tın tekstüre sahip topraklar bitki gelişimi bakımından fiziksel ve kimyasal özellikleri optimum koşulları sağlamaktadır. Bitki besin elementi içeriği, su ve hava dolaşımı ve kapasiteleri iyidir. Tarım için en ideal topraklar kumlu tın ile killi tın arasındaki tınlı topraklardır. Tınlı topraklar bitki gelişimi için ideal koşulları sağlamaktadırlar (Çepel, 1996). Kilis ili tarım topraklarının yarısından fazlası kil bünyeye sahip olurken, % 30'u killi tın ve % 15'i ise tın bünyeli olarak tespit edilmiştir. Örneklenen tarım arazileri, tekstür yönünden tarımsal üretim için uygun bulunmuştur. Tekstür ile besin maddesi alımı arasında bir ilişki olduğu yapılan bazı çalışmalarla belirlenmiştir. (Karadavut ve ark., 2011) toprakta silt ve organik madde arasında pozitif ilişki bulunurken, toplam azot içeriği ile kum içeriği arasında önemli düzeyde negatif ilişki bulunmuştur. Kaba bünyeli toprakların su besin maddesi tutma özelliği zayıf olmaktadır.

Topraklar kireç içeriği yönünden değerlendirildiğinde, % 22.5'inin fazla, % 7.5'inin çok fazla kireçli olduğu belirlenmiştir. % 67.5'i orta kireçli olan Kilis ili toprakları genel olarak kireçli topraklar sınıfında yer almıştır. Ana materyalin yer yer kireçtaşı kalkerden oluşması il topraklarının kireç oranının yüksek olmasının sebebi olduğu düşünülmektedir. Toprakta kirecin kimyasal ayrışması sonucu toprakların pH'sının da arttığı düşünülmektedir (Uysal ve ark., 2016). Tarım topraklarının kireç içeriği ve pH'sı yüksek olduğu durumlarda bitki besin elementlerinin alımı ve yarayışlılığı sınırlandırılmaktadır (Kaçar, 1994). Kireçli topraklarda makro besinlerin yanında bazı mikro besinlerin de alımı sınırlanmaktadır. Zn uygulaması ile mısır bitkisinin kuru madde verimi ve Fe alımının arttığı istatistiksel olarak anlamlı bulunduğu bildirilmiştir (Adiloğlu, 2003).

Toprakların % 24'ünün fosfor içeriğinin çok az, % 14'ünün az ve sadece % 2'sinin fosfor içeriğinin orta düzeyde olduğu tespit edilmiştir. Kireç içeriği yüksek alanlarda fosfor besin elementinin yarayışlılığı azalmaktadır. Buna karşın toprak kolloidlerinde fosforun fiksasyonu artmaktadır. Tarım topraklarında yer yer kireç içeriğinin yüksek olduğu noktalarda toprağın fosfor içeriği yüksek bulunmuştur (*Tablo.5*). Tarım topraklarımızın fosfor içeriği genellikle düşük miktarlardadır. Yerkabuğundan bulunan ve fosfor içeren Apatit gibi primer toprak mineralleri toprağın fosfor içeriğine katkıda bulunmaktadır (Karkanas ve Goldberg, 2010). Ülkemiz topraklarının besin maddesi içeriğinin belirlendiği birçok çalışmada, yaygın fosfor noksanlığı olduğu belirlenmiştir (Akça ve ark., 2015). Manisa ili Turgutlu ilçesi bağlarında alınan toprak örneklerinin besin elementi analizleri ile incelenmiş ve toprak örneklerinin % 50'si azotça, % 63'ü fosforca, % 57'si potasyumca fakir olduğu belirtilmiştir (Tepecik ve ark., 2014).

Kilis ili toprakları potasyum içeriği yönünden ortalama 76.77 kg/da^{-1} olarak belirlenmiş olup Ülgen ve Yurtsever (1995)' e göre fazla potasyum içeren topraklar sınıfında yer almıştır (*Tablo.4*). Ülkemiz toprakları potasyumca zengin topraklardır. Feldspat ve mika içeren kayaçlar toprağın potasyum kaynağını oluşturmaktadır.

Bazı çalışmalarda kum içeriği yüksek kaba bünyeli toprakların potasyum içeriklerinin düşük olduğu belirlenmiştir (Çelik ve Dengiz, 2018).

4. Sonuç

Tarımsal üretimin kuru koşullarda yapıldığı Kilis ili tarım topraklarının hafif alkali reaksiyonlu olduğu ve pH bakımından tarıma uygun olduğu, killi tın ve tınlı topraklardan oluştuğu ve bitki besleme yönünden uygun tekstüre sahip olduğu belirlenmiştir. En fazla kireç % 56.146 ile Akçaağıl köyünden alınan örneklerde tespit edilmiş ve Kilis ilinde tarımsal üretim yapılan topraklar, ortalama % 14.067 kireç içeriği ile orta düzeyde kireçli topraklar olduğu belirlenmiştir. Organik madde içeriği ortalama % 1.68 ile az, alınabilir fosfor içeriği ortalama 3.16 kg/da^{-1} ile az, alınabilir potasyum ortalama 76.77 kg/da^{-1} ile fazla olduğu belirlenmiştir. Kilis ili tarım topraklarının tuzsuz olduğu ve bunun tarımsal üretim için önemli bir avantajdır. Tuzsuz toprakların varlığının korunması gerekmektedir. Uzun yıllar yağış ortalaması 350-450 mm arasında değişen Kilis ilinde yağış azlığı besin maddelerinin yarayışlılığını sınırlandırmaktadır. Yoğun kireç içeriğine sahip bu topraklarda fosfor gibi verimliliğe etki eden bazı önemli besin maddelerinin de alınabilirliği azalmaktadır.

Üreticilerin gübreleme konusundaki yetersizlikleri, toprakta var olan besin maddesinin tüketilmesi sonucunda, yıllar itibariyle ürün veriminde azalmalar görülmektedir. Gübreleme yetersizliğinin yanında azaltılmış toprak işleme, nadas ve ekim nöbeti gibi toprağın verimliliğini koruyan uygulamaların yetersizliği, il topraklarının verim gücünü azalmasını sağlamaktadır. Üreticiler toprak analizlerini düzenli olarak yaptırmalı, analiz sonuçlarına göre toprakta yetersiz bulunan besin elementi bitkinin ihtiyaç duyduğu dönemde toprağa ilave edilmelidir. Gübreleme toprak verimliliğinin devamı için gerekli bir uygulamadır. Fosforlu gübrelerin ekimle beraber taban gübresi olarak, azotlu gübrelerin ise üst gübre olarak verilmesi uygundur. Özellikle organik gübrelerin uygulanması ilimiz üreticilerine önerilmektedir.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Evaluation of Water Levels and Flow Rates Measured in Irrigation Canal Using Limnigraph, Pressure and Ultrasonic Sensors*

Sulama Kanalında Limnigraf, Basınç ve Ultrasonik Sensörler Kullanılarak Ölçülen Su Seviyeleri ve Debilerinin Değerlendirilmesi

Cafer GENÇOĞLAN[1*], Mehmet Durak TÜYSÜZ[2], Serpil GENÇOĞLAN[3]

Abstract

Anything that cannot be measured cannot be managed. Based on the thought, the aims of this study are to evaluate water levels and flow rates measured by Limnigraph (OEL), pressure sensor (PS) and ultrasonic sensors (US) in the open irrigation canal. Limnigraph and pressure sensor sensed water levels and flow rates under un-fluctuating conditions in the Stilling Well and ultrasonic sensors directly measured them from water surface under fluctuating conditions at the Kartalkaya Dam in Kahramanmaraş. Assuming Limnigraph water level and flow rates readings correct and water levels and flow rates of Limnigraph were compared with that of pressure and ultrasonic sensor. Mean Absolute Percentage Error (MAPE) and ANOVA tests were done on 2454 observations. Average of water level and flow rates of limnigraph, pressure and ultrasonic sensor were 928±4.9 mm and 4.61±0.038 m^3s^{-1}, 927±4.9mm and 4.62±0.037 m^3s^{-1}, and 922±4.9 mm and 4.58±0.037 m^3s^{-1}, respectively. Differences between the average water levels and flow rates were 1 mm (928-927) and 0.01 m^3s^{-1} (4.61-4.62) under un-fluctuating and 6 mm (928-922) and 0.03 m^3s^{-1} (4.61-4.58) under fluctuating conditions. The fluctuation increased the differences between the average water levels and flow rates. MAPE of water levels and flow rates for pressure and ultrasonic sensor were calculated as 0.741% and 1.466% under un-fluctuation, and 1.453% and 2.490% under fluctuation conditions, respectively and since they were below 10%, the levels of agreement between the two data sets are considered as “very good”. However, fluctuation conditions increased MAPEs from 0.741% to 1.453%, from 1.466% to 2.490%. The water levels and flow rates of both sensors were not statistically different from those of optic encoder Limnigraph. Accordingly, both sensors can be used to measure water levels and flow rates in open irrigation canal but un-fluctuating conditions should be preferred. In addition, ultrasonic sensors can be used in environments that block, corrode the pressure sensors and make it difficult to use by floating objects.

Keywords: PLC, Pressure and ultrasonic sensors, Stilling well, Water head, Rating curve.

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Öz

Ölçülemeyen hiçbir şey yönetilemez. Bu düşünceden hareketle, bu çalışmanın amacı, açık sulama kanalında Limnigraph (OEL), basınç sensöru (PS) ve ultrasonik sensör (US) ile ölçülen su seviyelerini ve debilerini değerlendirmektir. Kartalkaya Barajı'nda sol sahil sulama kanalında su seviyesi ve debiler, sulama mevsiminde akım gözlem istasyonunda (AGİ) ölçülmüştür. Akım gözlem istasyonunda limnigraf ve basınç sensörü, su seviyelerini dalgalanmayan koşullar altında ve ultrasonik sensörler ise dalgalı koşullar altında doğrudan su yüzeyinden ölçmüştür. Limnigraph'ın su seviyesi ve debi değerlerinin temel alınarak, basınç ve ultrasonik sensörün su seviyeleri ve debi değerleri ile karşılaştırılmıştır. Ortalama Mutlak Yüzde Hatası (MAPE) ve ANOVA testleri 2454 gözlem değeri üzerinde yapılmıştır. Limnigraf, basınç ve ultrasonik sensörün ortalama su seviyesi ve debisi sırasıyla 928±4.9 mm ve 4.61±0.038 m^3s^{-1}, 927±4.9 mm ve 4.62±0.037 m^3s^{-1}, 922±4.9 mm ve 4.58±0.037 m^3s^{-1}'dir. Ortalama su seviyeleri ve debiler arasındaki farklar, dalgasız ortamda 1 mm (928-927) ve 0.01 m^3s^{-1} (4.61-4.62), dalgalı koşullar altında 6 mm (928-922) ve 0.03 m^3s^{-1} (4.61-4.58)'dir. Basınç ve ultrasonik sensörün belirlediği su seviyeleri ve debilerinin MAPE'si dalgasız koşullarda sırasıyla %0.741 ve %1.466, dalgalı koşullarında ise %1.453 ve %2.490 olarak hesaplanmıştır. Bu değerler, %10'un altında oldukları için iki veri seti uyumu "çok iyi" olarak kabul edilmektedir. Dalgalanma koşullar, MAPE değerleri %0.741'den %1.453'e, %1.466'dan %2.490'a yükseltmiştir. Dalgalı koşullar ortalama su seviyesi ve debi değerleri arasındaki farkı ve MEPA değerlerini artırmıştır. Her iki sensörün su seviyeleri ve debileri, limnigrafın değerlerinden istatistiksel olarak farklı değildi. Buna göre, açık sulama kanalında su seviyelerini ve debileri ölçmek için her iki sensör de kullanılabilir ancak dalgalı olmayan koşullar tercih edilmelidir. Ayrıca ultrasonik sensörler, basınç sensörlerini tıkayan, aşındıran ve yüzen nesneler tarafından kullanılmasını zorlaştıran ortamlarda kullanılabilir.

Anahtar Kelimeler: PLC, Basınç ve ultrasonik sensör, AGİ, Su yükü, Anahtar eğrisi

1. Introduction

Since climate change is experienced and water is scarce on world, freshwater should be managed effectively (Li et al., 2020; Çetin et al., 2020; Ali et al., 2021). In Turkey, around 74% of fresh water is used in irrigation (Ministry of Development, 2018). The majority of the irrigation water is distributed through the open canal system with low efficiency in agricultural schemes (Çakmak and Tekiner, 2010). Especially in arid and semi-arid regions where water resources are scarce, the most efficient use and management of irrigation water has become a very important issue. As is mentioned by Garvin (1993), anything that cannot be measured cannot be managed. Therefore, the flow rates of irrigation water have been measured with a limnigraph or limnimeter using the rating curve at the beginning of the main irrigation canal. However, at the beginning of secondary and tertiary canal, it is measured using only limnimeter and rating curve (Acatay, 1996; Léonard et al., 2000). In addition, the water level in rivers, drainage canals, dams, lakes, flood controls and wastewater management are measured with limnigraph or limnimeter (Meral and Benli, 2013). Limnimeters are made of wooden or metal with different lengths and scaled in centimeters. Limnigraphs have different measurement systems such as float-optic encoder, magnetic encoder, radar, ultrasonic and pressure sensors. Of these, magnetic and float limnigraphs measure the water level mechanically. On the other hand, the rating curve is the function (Q=f(h)) of the water levels (h) measured in a certain cross-section of a stream (Chow et al., 1988; Léonard et al., 2000; Tülücü, 2002; Çetin et al., 2020).

The first water depth measuring instruments was limnimeters. Later, float limnigraphs (optic encoder limnigraph) were developed (Chow et al, 1988). The optic encoder limnigraphs have an LED light source, a light detector, a “code” disc/wheel mounted on the shaft, and output signal processor.

The sensor technology is the key for measurement and automation (Zhao and Wen, 2008). Therefore, in this study, pressure and ultrasonic sensors were used as limnigraph. A pressure sensor is a device that senses pressure and converts it into an electric signal where the amount depends upon the pressure applied (Trout, 1986; Huang et al., 2019). Pressure sensors are widely used in hydrogeological and hydrological sciences for monitoring water levels (Sorensen and Butcher, 2011) and water level could be measured with high accuracy (Yuliza et al., 2016). Pressure sensors have some advantages such as accurate measurement in low flow water, being suitable to be installed in river with steep slope elevation and less need for maintenance. They have some disadvantages such as accuracy drops in high flow condition, difficulty in maintaining as the sensor body may submerge in river sedimentation and susceptible to lightning surge problem (Hydrological Procedure, 2018). On the other hand, an ultrasonic sensor sends the ultrasonic wave towards an object at the speed of sound, and the echo that hits the object returns to the detector. The distance from the sensor to the object is calculated according to the time elapsed between sending the wave and returning the echo (Fisher and Sui, 2013; Varun et al., 2018). Ultrasonic sensors have some advantages such as accurate reading in both low and high flow conditions, no contact with water, making it easy for maintenance and no lightning surge problem and they have some disadvantages as fallows; susceptible to blockage of object which will result in reading error. Limitations such as deadband and bean angle, which require ultrasonic water level sensor to be installed at correct position. Ultrasonic wave is more sensitive, which may cause errors in reading, especially in water with debris. In addition, it is not suitable to be installed at area with high elevation riverbank (Hydrological Procedure, 2018).

To measure water levels and flow rates with float limnigraph (encoder optic limnigraph) in open irrigation canal it is needed a special expensive structure called stilling well, but no need it for pressure and ultrasonic sensors. Pressure sensors measure water levels directly since they are submergible, and ultrasonic sensors needs only a buttress. In addition, getting the accurate measurement in open canal is more difficult because there is an influence of external factors such as the formation of the wave, irregular channel structures and floating objects on the water surface (Rahman et al., 2017). In this context in the last 40 years, water level measurement studies have been carried out in laboratory conditions using pressure and ultrasonic sensors. However, studies that directly measure water level and flow rate in irrigation canals using these two sensors are very limited. In Turkey, PSs are used much less but USs much more in water level and flow rate measurement.

Using pressure sensor, the following studies were conducted. Trout (1986) measured water level in open canal. Harlan et al. (2021) determined flow rates in river. The water velocity in a rectangular canal was measured by integrating-float method under laboratory conditions and then the flow rate was calculated (Abed, 2021). In a study by Çetin et al. (2020), water levels and flow rates were measured using float limnigraph (encoder optic limnigraph)

both in irrigation and drainage canals. Gençoğlan and Gençoğlan (2016) and Gençoğlan et al. (2021) measured water level in Class A pan in workshop and field conditions.

Flow rates in open canals were monitored using an ultrasonic sensor under laboratory conditions by Dusarlapudi et al. (2020) and Koshoeva et al. (2021), and the water levels were measured in open canals by Nirupam et al. (2015), Rahman et al. (2017), Sai (2017) and in tanks by Kumar and Verma (2015), Varun et al. (2018), Bello et al. (2018), Selvan et al. (2018), Mohammed et al. (2019) and in the rivers by Meral and Benli (2013), Machado, et al. (2021). For rivers, they also calculated flow rates using water level and rating curve. In Turkey, in recent years, water levels and flow rates have started to measure by using ultrasonic sensors in dams, irrigation regulators and main open irrigation channels. On the other hands, using ultrasonic sensor, some researchers had measured the water level in Class A pan to determine pan evaporation (Gençoğlan et al., 2013; Fisher and Sui, 2013; Sezer et al., 2017; Gençoğlan et al., 2022).

In accurate measurement for water level and flow rates in open irrigation canal, selection and use of the right measuring device and technique are important. With the development of technology, sensors such as PSs and USs and others have started to replace OEL because expensive structure like Stilling Well is needed to measure water levels and flow rates with OEL. PSs and USs do not need it and need only panel. In recent years, PSs and USs have been increasingly used in measuring water levels and flow rates in open irrigation canal.

The aim of this study is to evaluate the water levels and flow rates measured by OELs, PSs and USs in the open irrigation canal.

2. Materials and Methods

The study was carried out at the flow gauging station (FGS) located on the left bank main (conveyance) irrigation canal of the regulator of Kartalkaya Dam. Kartalkaya Dam is located 30 km southeast of Kahramanmaraş province. The measurements were done in the trapezoidal section, concrete-lined, left bank open irrigation canal in irrigation season in 2017.

At FGS, there was no collection of water, erosion and siltation since open canal was lined with the concrete. FGS had a Stilling Well of 80x80x240 cm and also 30 cm diameter and 3 m long pipe on which there was a shelter of 80x50x60 cm. The float limnigraph was available at the FGS. At FGS, a panel (50x50x80 cm) was placed under the shelter to measure the water levels and flow rates at cross-section of the open irrigation canal using pressure and ultrasonic sensor (*Figure 1*). In order to provide energy to the panel, the solar panel was installed on the guardrails of the observation bridge, in such an angle that it could receive the full sun, and the ultrasonic sensor was attached perpendicular to the water surface at the lower part and the middle point of the bridge (*Figure 2*). Inside the panel, there are circuit breaker, PLC, SD card module, analog module, solar regulator, inverter, power supply, router-modem with FTP, 3G vinn modem, and electrical outlet. The solar panel charged a battery, which was placed in the float limnigraph shelter, and it supplied power to the instruments in the panel.

In FGS, there was available float limnigraph (Optic Encoder Limnigraph, OEL). It was measuring the water level and flow rate mechanically by means of a float system and was configured to record them in 15 minutes interval by DSİ. Specification of OEL; accuracy is 1mm, tolerance ±1mm, logging time range 1, 5, 10, 15, 60....1440 minutes, output 4...20 mA, power 3.6V. The measured water level and calculated flow rates at FGS were recorded in the EEPROM of OEL. Computer was connected to OEL via the RS232 protocol using the interface program and the measured 2454 water level and flow rates were downloaded to the computer.

In the current study, measuring interval of pressure and ultrasonic sensor was selected 15 minutes since measuring interval of OEL was 15 minutes, and time was coincided.

The pressure sensor has input power 10-32 DCV and output 4-20 mA (Karabacak, 2003; Hashemian and Jiang, 2009). Its measurement capacity is 400 mBar, which is equal to water level of 4000 mm H_2O. Its standard accuracy is ≤±0.5% full scale (FS) or of span (Atek, 2020).

The input and output of the ultrasonic sensor is 24 VDC and 4-20 mA, and its sensing range is between 60-2000 mm, and adjustment range is between 90-2000 mm and repeat accuracy is ± 0.1 % of full-scale value (Pepperl and Fuchs, 2022).

The PLC has six digital inputs (DI, 24 VDC), six digital outputs (DO, 24 VDC, 0.5 A max., with transistor), 2 analog inputs (AI, voltage 0...10 V), 1 analog output (AO, voltage 0...10 V or current 0...20 mA/4...20 mA).

Analog (AI/AO) module had four configurable AI, 2 configurable AO, resolution 11 bits plus signal or 12 bits and measuring range from 0 to 27648 for 4-20 mA.

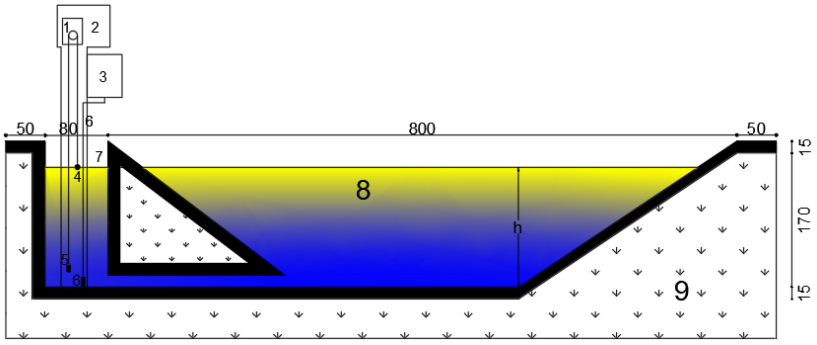

Figure 1. Cross section of trapezoidal type main irrigation canal and FGS (1-Limnigraph, 2-Limnigraph shelter, 3-PLC panel, 4-Limnigraph ball, 5-Limnigraph weight, 6- pipe, 7-FGS box, 8-Water cross-section, 9 -Canal fill section)

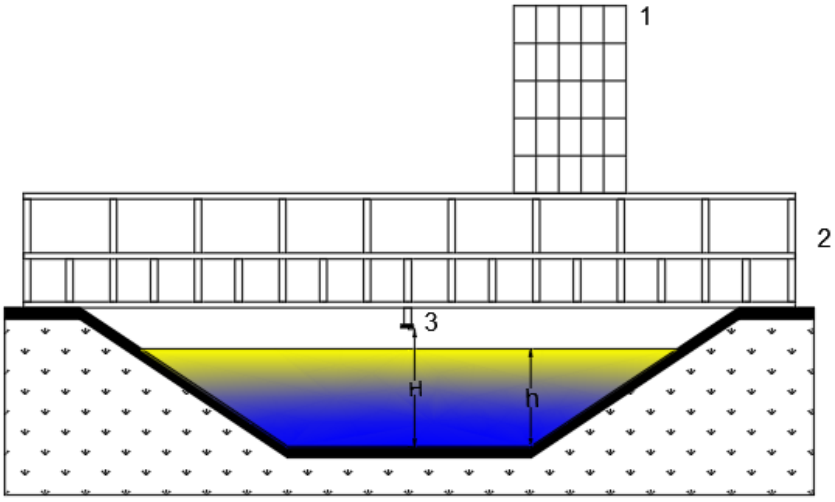

Figure 2 Trapezoidal main canal, bridge section and solar panel (1-solar panel, 2-bridge, 3-ultrasonic sensor)

Water levels and flow rates read by OEL were assumed to be correct and they were compared with water levels and flow rates of pressure and ultrasonic sensor. Measurement times of water levels and flow rates of pressure and ultrasonic sensor were coincided with the OEL's time, at 15-minute intervals. Since the water level in the open canal is affected by the fluctuation, in order to minimize its effect, successive 30 water levels were measured every 300 ms and their moving average was taken (Tülücü, 2002; Gençoğlan et al., 2013).

The digital water levels measured by pressure and ultrasonic sensor were converted to the water levels in millimeter using Equation 1 and 2, respectively.

$$h_{ps} = \frac{ps_{dv}x4000}{27648} \quad \text{(Eq. 1)}$$

$$h_{us} = H - \frac{us_{dv}x2000}{27648} \quad \text{(Eq. 2)}$$

Where, h_{ps}; water level measured with pressure sensor (mm) ve ps_{dv}; pressure sensor digital value, h_{us}; water level measured with ultrasonic sensor (mm), H; distance between canal floor and ultrasonic sensor (mm), us_{dv}; ultrasonic sensor digital value. The digital value of 27648 in Equation 1 and 2 corresponds to 4000 mm in pressure sensor and 2000 mm in ultrasonic sensor for 20 mA.

Since management of canal is under State Hydraulic Work (DSİ) and it was impossible to measure data of rating curve by us on the left bank of the regulator and therefore, the data of the rating curve was taken from DSİ (DSİ, 2017). Rating curve data consisted of independent (water levels) and dependent parameter (flow rates) (Alfa et al., 2018). The water level in the rating curve of the canal varies between 100-1610 mm and the flow rate between 0.2-12.050 m^3s^{-1}. To be able to use the key curve in the PLC program, a regression analysis was performed between 152 water levels and flow rates to establish polynomial rating curve. The curve was established as in Equation 3.

$$Q=ah^2+bh+c \quad \text{(Eq. 3)}$$

Where, Q; flow rates (m^3sn^{-1}) and h water level (mm).

In irrigation canal, the flow rates were predicted directly by substituting h_{ps} and h_{us} for h in Equation 3.

A PLC project was created and then, a program was written in CODESYS-ST language to automatically determine the water levels and flow rates. This program consisted of two parts. The first section contained the program codes, and the second section is the visualization section, in which the instantaneous water levels and flow rates in the canal were directly visualized. In this project, an analog module was added to the PLC in order to read the pressure and ultrasonic sensor analog outputs. Since the pressure and ultrasonic sensor analog outputs are 4-20 mA, the input of the analog module was selected as 4-20 mA. The addresses of these inputs are %IW0 and %IW1. The types of these addresses are INT. IP numbers should be the same group in order to establish the network connection between the computer and the PLC. Web and FTP servers were activated for remote connection. Web port is taken as 80 and FTP as 21. Water levels and flow rates were recorded in SD card in every 15 minutes (Machado et al., 2021). The second section visual display interface was made in order to instantly monitor the water levels and flow rates in the open canal on the visual screen via the web browser.

Mean Absolute Percentage Error (MAPE) (Lewis, 1982) for the water depth and flow rates of PS and US were calculated from Equation 4. It is an expression of the deviation of the water depth and flow rates measured by OEL in the irrigation canal from the water depth measured by pressure and ultrasonic sensor.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{|WD_{OELi} - WD|}{WD_{OELi}}100\right) \quad \text{(Eq. 4)}$$

Where, WD_{OELi}; water depth measured by pressure sensor (mm), WD; water depth measured by pressure and ultrasonic sensor (mm), n; the number of observations (2454 times).

In addition, the ANOVA tests were performed in the Minitab program to determine whether there is a difference among the water levels and flow rates measured by the EOL, PS and US.

3. Results and Discussion

In this study, the water level and flow rates were measured by Optic Encoder Limnigraph (OEL), pressure (PS) and ultrasonic sensor (US) in open irrigation canal at FGS in the Kartalkaya Dam. Water levels and flow rates read by OEL were assumed to be correct and they were compared with water levels and flow rates of pressure and ultrasonic sensor. OEL and PS measured them in Stilling Well (under un-fluctuating) and US directly from water surface (under fluctuating).

At FGS, a quadratic rating curve equation was determined as $Q=3*10^{-6}h^2+0.0021h+0.0134$ ($R^2=0.9995$). A close relationship was determined between the water levels and the flow rates and it means that the water levels represent 99.95% flow rates. Accordingly, the flow rates in FGS show that it is highly dependent on the water levels. Clarke (1999) reports that R^2 of rating curves is often close to 1, which means that the estimated flow rates will have high accuracy. Meral and Benli (2013) found rating curve equation as $Q=3.0523h-0.5569$ ($R^2=0.8563$). The researchers found first-order equations between the water level and flow rate, measured in the Aksu river. Kukul (2008) determined rating curve as $Q= 8.786h^2+91.855h-95.990$. In the study by Ardıçlıoğlu and İlkentapar (2015), the rating curve was determined as $Q=7.09h3.42$ ($R^2=0.99$). Generally, the degree of the rating curves varies according to the cross-sectional area and the water velocity.

The variance analysis was performed for OEL, PS and US water levels and flow rates and its results were found to be insignificant ($P>0.05$). According to these results, there is no statistical difference among OEL, PS and US

water levels and flow rates. These results show that water levels and flow rates using the rating curve can be measured by PS and US in a trapezoidal main irrigation canals.

The levels of agreement between the water levels of OEL and PS, and OEL and US were calculated as MAPE of 0.741% and 1.453%. They are considered as "very good" since MAPE is below 10% (Lewis, 1982). The averages of 2454 water levels were determined as 928±4.9 mm for OEL, 927±4.9 mm for PS, and 922±4.9 mm for US, respectively (*Table 1*). As seen in the figures, differences between the average water levels of OEL and PS, and OEL and US were 1 and 6 mm, respectively. The average 6 mm difference in water levels may be due to the fact that OEL measured the water level in un-fluctuating conditions but US in fluctuating conditions. Under un-fluctuating conditions, difference between average levels measured by OEL and PS was found as 1 mm. Although sensitivity of PS is higher than that of US (Nirupam et al., 2015), difference in water level read by PS was lower than that of US. Accordingly, the average water level difference measured in the Stilling Well (un-fluctuating) conditions decreased. The results were supported by MAPE since MAPE of 0.741% under un-fluctuating conditions was less than that of 1.453% under fluctuating conditions. There was a difference between the water level measured in un-fluctuating and the water level measured in fluctuating conditions, but it was not statistically significant.

The lowest water levels measured by OEL, PS and US were 250 mm, 181.7 mm and 154.8 mm and the highest 1270 mm, 1266 mm and 1276 mm, respectively. In addition, it was observed that the OEL's, PS's and US's water levels distributed on and around the diagonal line in *Figure 3* and *4*. It was sighted that PS's and US's water levels were lower than that of OEL when the water levels were below about 600 mm. The slope and determination coefficient between OEL and PS, and OEL and US were found to be S=0.9981 and R^2=0.9992, and S=0.9934 and R^2=0.9969, respectively and they were close to each other's (*Figure 3* and *4*). Water levels measured using by US (Gençoğlan et al., 2013) and by PS (Gençoğlan and Gençoğlan, 2016) in Class A pan resulted acceptable under fluctuation and un-fluctuation conditions. In studies by Kumar and Verma (2015), Yuliza et al. (2016), Rahman et al. (2017), Prayash (2017), Bello et al. (2018) and Selvan et al. (2018), it was concluded that performance of US was at the desired accuracy. Dusarlapudi et al. (2020) proposed that US was cost effective and highly accurate with an accuracy range of 96 – 98%. When results of water levels sensed by PS and US were compared, the results of this study correlate with the water levels ranges reported in the existing studies.

Table 1. Average water levels and flow rates measured by OEL, PS and US, and results of MEPA

	Average water levels (mm)	Average flow rates ($m^3 s^{-1}$)	MEPA for water levels	MEPA for flow rates
OEL	928±4.9	4.61±0.038		
PS	927±4.9	4.62±0.037	0.741	1.466
US	922±4.9	4.58±0.037	1.453	2.490

The levels of agreement between the flow rates of OEL and PS, and OEL and US were calculated as MAPE of 1.466% and 2.490%. The levels of agreement between the two data sets are considered as "very good" since MAPE is below 10% (Lewis, 1982). Using the rating curve, Ardıçlıoğlu et al. (2010) found flow rate of 9.4% error in rivers, and Ardıçlıoğlu and İlkentapar (2015) found flow rate of 3.8% error in open canal.

The flow rates were calculated by substituting the water levels in $Q=3*10^{-6}h^2+0.0021h+0.0134$ rating curve. The averages of 2454 flow rates for OEL, PS and US were 4.61±0.038 m^3s^{-1}, 4.62±0.037 $m^3 s^{-1}$ and 4.58±0.037 $m^3 s^{-1}$, respectively (*Table 1*). Difference between OEL and PS, and OEL and US flow rates was found as to be 0.01 $m^3 s^{-1}$ and 0.03 $m^3 s^{-1}$, respectively. The average flow rate difference of 0.03 $m^3 s^{-1}$ determined for US under fluctuating conditions was higher than that of 0.01 $m^3 s^{-1}$ for PS under un-fluctuating conditions. Therefore, the average flow rates difference measured under open irrigation conditions decreased (Pereira et al., 2022). The results were supported by MAPE since MAPE of 1.466% under un-fluctuating was less than that of 2.490% under fluctuating conditions. There was a difference between the flow rates under un-fluctuating and fluctuating conditions, but it was not statistically significant.

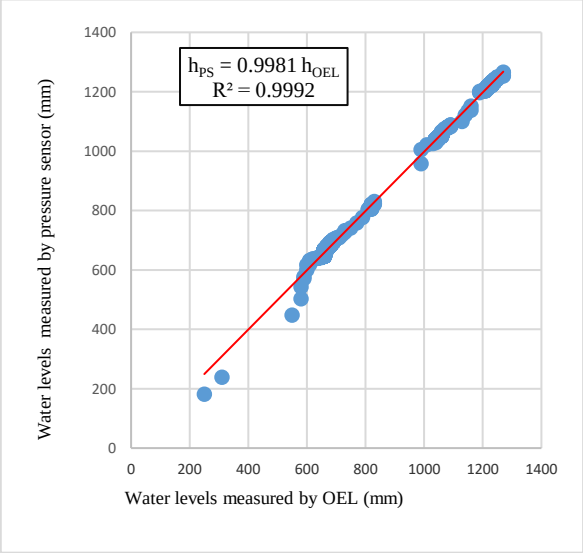

Figure 3. Optic encoder limnigraph-pressure sensor water levels

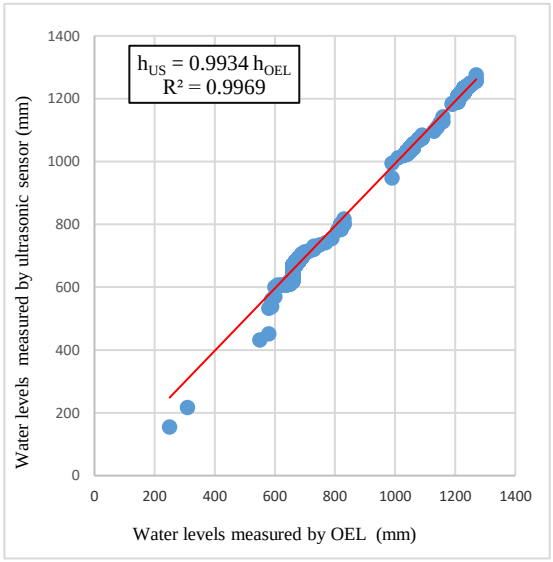

Figure 4. Optic encoder limnigraph -ultrasonic sensor water levels

The lowest and highest flow rates of OEL, PS and US were 0.61 m^3 s^{-1} and 7.41 m^3 s^{-1}, 0.475 m^3 $s^{-1}$and 7.358 m^3 s^{-1} and 0.394 m3 s-1 and 7.453 m^3 s^{-1}, respectively (*Figure 5* and *6*). As seen the figure, OEL, PS and US flow rates are distributed on and around the diagonal line and PS and US flow rates were lower than OEL values when the flow rates fell below about 1.4 m^3 s^{-1}. Slope and R^2 were determined between OEL and PS, and OEL and US flow rates as S=0.9983 and R^2=0.9986, S=0.9921 and R^2=0.997, respectively (*Figure 5* and *6*). Their slopes and determination coefficient were very close to each other's. In the US study conducted by Koshoeva et. al (2021), it was reported that result of flow rates was of high accuracy. When flow rates read by PS and US were compared, the results of this study correlate with the flow rates ranges reported in the existing study.

As can be seen from the studies given above, the number of water level studies conducted using US is large but limited for PS and many of them were conducted under laboratory conditions. Results of this study shows that both sensors, no needing expensive structure, needing only panel, can be used to measure water levels and flow rates in open irrigation canal but un-fluctuating conditions should be preferred. In addition, ultrasonic sensors can be used in environments that block, corrode the pressure sensor and make it difficult to use by floating objects.

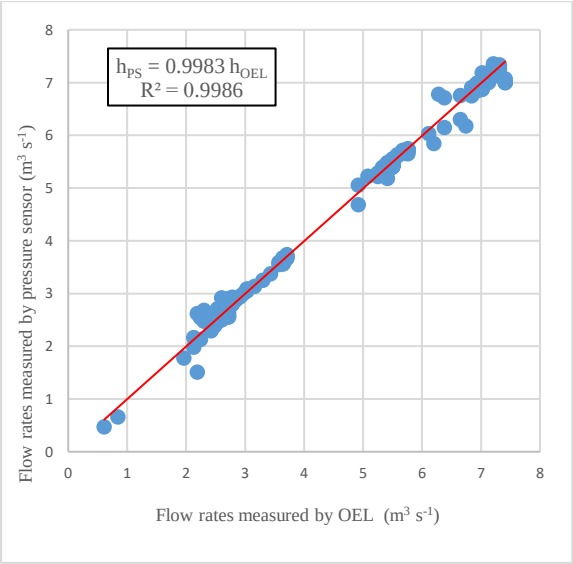

Figure 5. Optic encoder limnigraph-pressure sensor flow rates

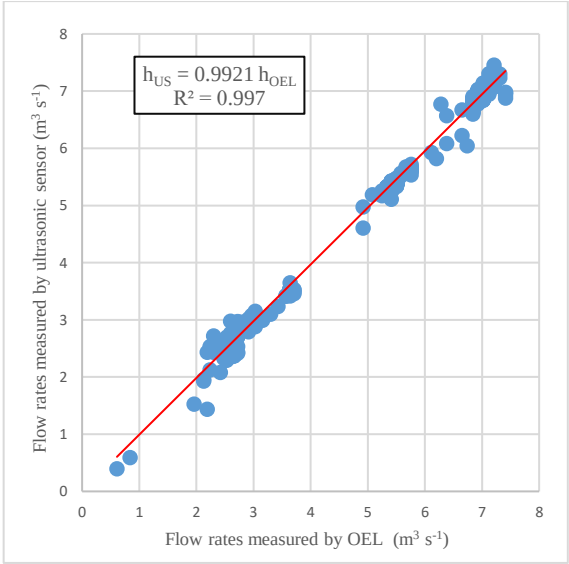

Figure 6. Optic encoder limnigraph - ultrasonic sensor flow rates

4. Conclusions

The study was conducted to measure water levels and flow rates using pressure sensor (PS) and ultrasonic sensors (US) in the open irrigation canal, and to compare water level and flow rates measured by optic encoder limnigraph (OEL) with that of pressure sensor and ultrasonic sensors in the flow gauging station (FGS).

In accurate measurement for water level and flow rates in open irrigation canal, selection and use of the right measuring device and technique are important. With the development of technology, sensors such as PSs and USs and others have started to replace OEL because expensive structure like Stilling Well is needed to measure water levels and flow rates with OEL.

Pressure sensor water levels were measured under waveless (un-fluctuating) conditions in the Stilling Well. The ultrasonic sensors water level was measured directly from the irrigation canal water surface in fluctuating conditions. Optic encoder limnigraph water levels and flow rates were taken as the baseline values in comparison with water levels and flow rates of pressure sensor and ultrasonic sensors. MAPE and ANOVA tests were done in observation of 2454 water levels and flow rates. The Averages of water level and flow rates of optic encoder limnigraph, pressure and ultrasonic sensor were 928±4.9 mm and 4.61±0.038 m^3s^{-1}, 927±4.9 mm and 4.62±0.037 m^3s^{-1}, and 922±4.9 mm and 4.58±0.037 m^3s^{-1}, respectively. Differences between the average water levels, and flow rates of OEL and PS, and OEL and US were 1 mm and 0.01 m^3s^{-1} under non-fluctuating and 6mm and 0.03 m^3s^{-1} under fluctuating conditions. MAPE of water levels and flow rates of pressure and ultrasonic sensor were calculated as 0.741% and 1.466% under un-fluctuation, and 1.453% and 2.490% under fluctuation conditions, respectively. The fluctuation increased the differences between the average water levels and flow rates of OEL and PS and which of OEL and US. Under un-fluctuation conditions, MAPEs are lower than that of fluctuation and since they are below 10%, the levels of agreement between the two data sets are considered as “very good”. The water levels and flow rates of PS and US were not statistically different from that of OEL. Using both PS and US, water level and flow rate can be measured in open irrigation canal but it should be preferred to measure water levels and flow rates at FGSs in which water is non-fluctuating. In addition, ultrasonic sensors can be used in environments that block, corrode the pressure sensor and make it difficult to use by floating objects.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

New Morphometric Approach to Discriminate Honey Bee (*Apis mellifera* L.) Populations in Türkiye

Türkiye'de Bal Arısı (*Apis mellifera* L.) Populasyonlarının Ayırt Edilmesi İçin Yeni Morfometrik Yaklaşım

Meral KEKEÇOĞLU[1*] Songül BİR[2], Merve KAMBUR ACAR[3]

Abstract

Today, 29 subspecies have been defined, each of which is adapted to a certain set of environmental characteristics, spreading all over the world except Antarctica. Many morphological and morphometric features have been used to classify honey bees from the past to the present. It has been reported that features such as length, angle and indices coming from the front wings are very efficient for classification. In recent studies, various programs have been developed and automatic classification has been attempted through the images of bee wings. This study aimed to determine the naturally occurring honey bee biodiversity in Turkiye by measuring 7 areas (A1, A2, A3, A4, A5, A6, A7) on the right front wing. For this purpose, a total of 3392 worker bee samples were collected from 143 colonies in 19 provinces of Turkiye. The photographs of the prepared preparations were taken at 1X magnification with the BAB camera system connected to the BAB STR45 stereozoom microscope. The measurements of 7 areas on the right front wings of honey bee populations distributed in Turkiye were made automatically in the BAB Bs200ProP program. Colony averages of the raw data of the area measurements of each province were taken and the results were evaluated with Discriminant Function Analysis (DFA) in the SPSS.15 package program. Multivariate analysis of variance (MANOVA) was applied to separate the groups to determine the variation within and between groups. As a result of this study, the minimum total area was seen in Van at 4.51 and the maximum total area was seen in Ardahan at 5.76. The average size of the measured areas decreased from the north-east to the south of Turkiye. Area measurements on the forewing were found to be a marker for distinguishing Anatolian (*A. m. anatoliaca*) and Caucasian (*A. m. caucasica*) honey bees.

Keywords: Türkiye, Anatolian honey bee (*A. m. anatoliaca*), Caucasican honeybee (*A. m. caucasica*), Front wing, Area

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Öz

Günümüzde Antartika kıtası hariç dünyanın her yerinde yayılış gösteren, her biri belirli bir çevresel özelliklere adapte olmuş 29 alt tür tanımlanmıştır. Geçmişten günümüze kadar bal arılarını sınıflandırmak için birçok morfolojik ve morfometrik özellikler kullanılmıştır. Yapılan çalışmalarda ön kanatlardan gelen uzunluk, açı ve indeksler gibi özelliklerin sınıflandırma için çok etkili olduğu bildirilmiştir. Son yıllarda yapılan çalışmalarda çeşitli programlar geliştirilmiş, arı kanatlarının görüntüleri aracılığıyla otomatik sınıflandırma yapılmaktadır. Bu çalışmada sağ ön kanatta yer alan 7 alan (A1, A2, A3, A4, A5, A6, A7) ölçülerek Türkiye'de doğal olarak bulunan bal arısı biyoçeşitliliğinin belirlenmesine çalışılmıştır. Bu amaçla Türkiye'nin 19 ilindeki 143 koloniden toplam 3392 işçi arı örneği toplanmıştır. Hazırlanan preparatların fotoğrafları BAB STR45 stereozoom mikroskobuna bağlı BAB kamera sistemiyle 1X büyütmede çekilmiştir. Türkiye'de yayılış gösteren bal arısı populasyonlarının sağ ön kanatları üzerindeki 7 alanın ölçümleri BAB Bs200ProP programında otomatik olarak yapılmıştır. Her ile ait alan ölçümlerinin ham verilerinin koloni ortalamaları alınarak sonuçlar SPSS.15 paket programında Diskriminant Fonksiyon Analizi (DFA) ile değerlendirilmiştir. Grup içi ve gruplar arası varyasyonun belirlenmesinde grupları ayırmada çok değişkenli varyans analizi (MANOVA) uygulanmıştır. Bu çalışmanın sonucunda minimum toplam alan 4.51 ile Van'da görülürken maksimum toplam alan 5.76 ile Ardahan'da görülmüştür. Ölçülen alanların ortalama büyüklüğü Türkiye'nin kuzey doğusundan güneyine doğru azalmıştır. Ön kanattaki alan ölçümlerinin Anadolu (*A. m. anatoliaca*) ve Kafkas (*A. m. caucasica*) bal arılarını ayırt etmede kullanılabilecek bir marker olduğu görülmüştür.

Anahtar Kelimeler: Türkiye, Anadolu bal arısı (*A. m. anatoliaca*), Kafkas bal arısı (*A. m. caucasica*), Ön kanat, Alan

1. Introduction

Honey bee diversity of the World is represented by the described 29 honey bee subspecies. Each of these is adapted to environmental conditions, also their fitness and adaption abilities enable them to spread all over the world except for the Antarctic region (Rahimi et al., 2018). Anatolia (Türkiye) has an extraordinary morphological diversification and evolutional patterns for honeybees. Ruttner (1988) classified honeybee races in this region as *A. m. anatoliaca*, *A. m. caucasica*, *A. m. meda*, and *A. m. syriaca* on the "O" branch. *A. m. caucasica* distributes along the eastern Black Sea coast, *A. m. meda* in the southeast, and *A. m. syriaca* in the south, near the border with Syria. *A. m. anatoliaca* occurs throughout the rest of Türkiye including Thrace. mtDNA studies showed that other subspecies have been found in the European part of Türkiye, Thrace, maybe *A. m. carnica* which belongs to the branch "C" of Ruttner's classification (Smith et al., 1997; Bodur et al., 2004, 2007; Kandemir et al., 2000, 2005). Kandemir et al. (2006a) reported the existence of a fourth new mtDNA lineage of *Apis mellifera* near the Syrian border of Türkiye (Franck et al., 2000). mtDNA analyses showed that *A. m. anatoliaca* and *A. m. caucasica* are closely related to the Eastern or "C" mitochondrial lineage (Smith et al., 1997; Palmer et al., 2000 Kandemir et al., 2006a; Özdil et al., 2009a, b; Özdil et. al., 2022; Bir and Kekeçoğlu, 2023) as do *A. m. carnica* and *A. m. ligustica*. But Ruttner's approach indicates *A. m. caucasica* and *A. m. anatoliaca* belong to a separate oriental group.

The first scientific studies describing honeybees were made according to standard morphometric methods. Many different morphological characters such as the length of the wings, tongue and other mouth apparatus, the length and width ratios of the plates of the tergite and leg segments, and the wing vein indexes were used (Bodenheimer, 1941; Settar, 1983; Ruttner, 1988; Güler and Kaftanoğlu, 1999a, b, c; Kandemir et al., 2000; Güler, 2000; Güler et al., 2002; Güler and Bek, 2002; Kandemir et al., 2005; Kekeçoğlu et al., 2007; Güler and Toy, 2008; Kekeçoğlu et al., 2009; Kekeçoğlu and Soysal, 2010; Güler et al., 2013; Koca and Kandemir, 2013; Çakmak et al., 2014). In the later studies, in addition to these morphometric characters, it has been tried to distinguish honey bees by using measurements such as the angle and index of the wings. Many studies have proven that front wing features are suitable characters to classify honey bees.

Morphometric studies of *Apis mellifera* L. to evaluate biodiversity, subspecies and intra-populational variability are very effective and convenient approaches for a long time (Ruttner et al., 1978; Ruttner, 1988; Mendes et al., 2007). Among other morphological features, wing venations patterns of honey bees were studied extensively covering angles, size of forewings and cubital index (DuPraw, 1965; Cournet and Fresnaye, 1989; Ruttner, 1987; Francoy et al., 2006). Contrary to traditional morphometrics employing size, masses and ratio of areas; relatively new geometric morphometric methods perform analyses by shape and form obtained arbitrarily of landmarks. The coordinate based geometric morphometric studies are found as the most robust approach accessible for the statistical analysis of shape (Rohlf, 2000a, b). Moreover, a comparison of both methods revealed unsuccessful and inadequate results using the classical method and encouraged applying new arrangements such as geometric morphometrics (Cavalcanti et al., 1999). In order to save time and energy, programs have been developed for image analysis on the computer. The basis of these programs is to transfer the image to the computer and transfer it to the automatic identification system with the determined points. Accordingly, more practical and easy automatic identification systems, such as TpsDig (Bookstein, 1991), ABIS (Schroder et al., 2002), DrawWing (Tofilski, 2004), DAWINO (Dicriminant Analysis With Numerical Outputs) (Uzunov et al., 2009), BAB Bs200ProP (Kambur and Kekeçoğlu, 2018; Kekeçoğlu 2018), DeepWings (Rodrigues et al., 2022), have been researched to classify honey bees through images of bees (Bookstein, 1991; Roth et al., 1999; Tofilski, 2004; Miguel et. al., 2011; Rodrigues et al., 2022).

The aim of the present work was to determine the morphometric variation of honey bees distributed in Türkiye, using the alternative image analysis method, which is area-based morphometric analysis. Area based geometric morphometric method is a relatively new technique that has generated valuable results in many fields of morphometry (Oettle et al., 2005; Nolte and Sheets 2005; Mendes et al., 2007; Kimmerle et al., 2008; Ogıhara et. al., 2008; Hayes et al., 2007; Francoy et al., 2009a,b). An application of the area-based morphometric method on Turkish honey bees is the first time in the present study.

2. Materials and Methods

A total of 3392 individuals from 143 colonies in 19 locations (Van, Hakkari, Tekirdağ, Kırklareli, Edirne, Zonguldak, Sakarya, Düzce, Artvin, Trabzon, Ordu, Isparta, Muğla, Gaziantep, Hatay, Kilis, Kahramanmaraş, Ardahan, Kars) of the seven regions of Türkiye were studied. Sampling was carried out mostly from, locally managed nonmigratory and requeening colonies in apiaries and 5-10 honey bee colonies were randomly chosen from per apiary, and all colonies were described by means of 15 worker bees. Preparation of sample collections for the microscope was done according to the method of Kekeçoğlu et al., (2020). The study material consisted of the right front wing of each worker bee. The photographs of slides were monitored at 1X magnification with the BAB camera system using stereozoom microscope. In this study, the measurements of 7 areas (A1, A2, A3, A4, A5, A6 and A7) on the right front wings were made in the BAB Bs200ProP program (BAB Imaging systems, BAB Ltd, 2007) (*Figure 1*).

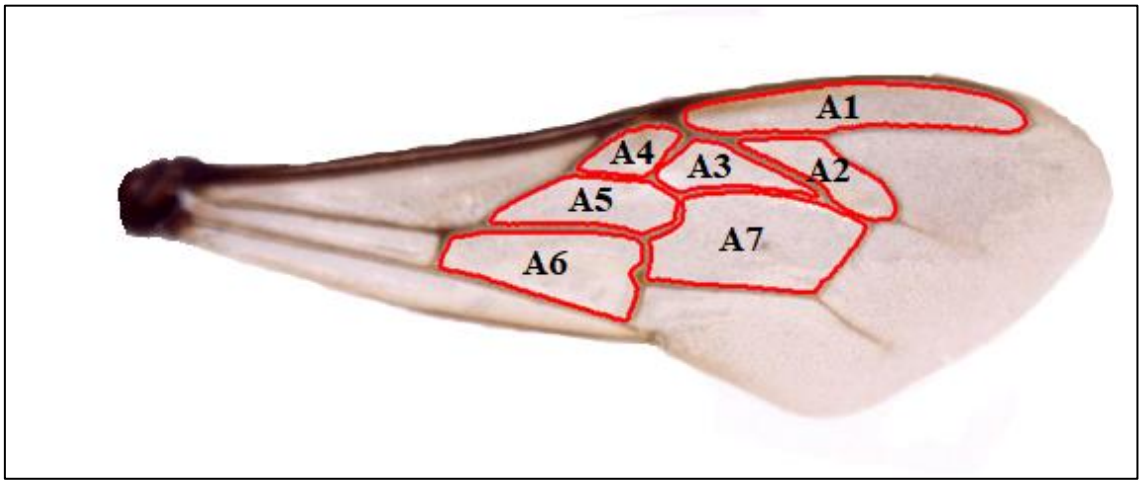

Figure 1. Forewings' areas measured on worker bees by using the BAB Bs200ProP programme

The measurement results of the worker bee samples representing each province were evaluated with Discriminant Function Analysis (DFA) in the SPSS.15 package program. Multivariate analysis of variance (MANOVA) was applied to determine the variation within and between groups. The Cross Validation Test (CVT) was performed to see the distribution of the populations among groups, and the distribution of the samples among the groups was determined.

3. Results

The morphometric variation of the honey bee population was determined for 19 different locations in Turkiye using area-based geometric morphometrics in the current study. For this reason 7 areas on the right fore wing were measured. Based on the measurements of seven area on the fore wing of worker honey bees from 19 different locations in Türkiye, it was concluded that the highest total area value was determined for Ardahan worker honeybee with 5.76, the lowest was seen in Van with 4.51.

The highest variability of A5 and A6 areas was found in honey bees from Artvin and Zonguldak. Honeybees from Artvin and Zonguldak showed the highest value (0.69 mm^2) for the A5 area and bees from Van showed the lowest value for all area. The analysis of variance revealed that the size of the wing area has significant differences between locations ($P < .05$). The size of the measured areas decreased from the north-east to the south of Türkiye.

The CVA based on the data of the seven areas of the right front wings showed that there was more overlapping among honeybee populations couldn't be identified clearly. The clusters plotted on the CVA graph are also relatively close each other, and intergaps between the groups were not shown clearly. Although Northeast and the rest part of Türkiye well separated with two axis: The population were placed mainly upper half, Trabzon, Zonguldak, Tekirdağ population mainly in lower-right-hand quandrant and small set of samples from Southeastern (Kilis) and Aegen (Muğla) in more lower-left-hand of the plot (*Figure 2).*

Tekirdağ, Trabzon, Zonguldak, Artvin, Ardahan, Sakarya and Edirne constitute a group in the phylogenetic tree drawn according to binary distances; Kırklareli, Isparta, Ordu, Düzce, Kahramanmaraş, Hakkari, Gazianatep, Kars, Muğla, Hatay and Van grouped together and a separate group close to Kilis was formed (*Figure 3*).

One-way ANOVA showed significant differences among honeybee populations. Out of the Düzce, Ordu and Kırklareli populations, generally all honeybee populations showed the expected classification schema by pairwise distance. There were significant size differences between Northeastern (Black Sea) and Southeastern (Kilis and Gaziantep). Honeybees from Central Anatolia and Eastern Anatolian region didn't differ significantly from each other.

Table 1. Front wing's area minimum (Min.) maximum (Max.). and average (X) values

	Colony number	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**Total**
LOCATION	**N**	**X ± Sx (Min.-Max.)**	**X ± Sx (Min.-Max.)**	**X ± Sx (Min.-Max.)**	**X ± Sx (Min.-Max.)**	**X ± Sx (Min.-Max.)**	**X ± Sx (Min.-Max.)**	**X ± Sx (Min.-Max.)**	**X ± Sx (Min.-Max.)**
		1,12±0,01	0,44±0,00	0,41±0,00	0,31±0,00	0,66±0,00	1,04±0,01	1,47±0,01	5,46±0,04
Tekirdağ	5	1,09-1,14	0,44-0,45	0,40-0,41	0,30-0,32	0,65-0,67	1,02-1,07	1,44-1,50	5,36-5,55
		0,96±0,00	0,38±0,01	0,36±0,01	0,27±0,01	0,57±0,01	0,91±0,01	1,28±0,01	4,71±0,05
Kırklareli	5	0,95-0,97	0,36-0,41	0,34-0,37	0,26-0,29	0,55-0,59	0,89-0,93	1,26-1,30	4,64-4,82
		1,07±0,02	0,42±0,01	0,39±0,01	0,28±0,01	0,65±0,01	1,01±0,01	1,40±0,01	5,21±0,09
Edirne	9	0,97-1,14	0,39-0,45	0,33-0,41	0,25-0,33	0,59-0,68	0,96-1,06	1,34-1,45	5,07-5,39
		1,15±0,01	0,47±0,01	0,44±0,01	0,32±0,01	0,69±0,01	1,08±0,02	1,55±0,02	5,70± 0,08
Zonguldak	9	1,07-1,21	0,44-0,49	0,39-0,48	0,30-0,34	0,63-0,75	1,00-1,17	1,44-1,66	5,28-6,08
		1,10±0,01	0,47±0,02	0,43±0,01	0,32±0,01	0,68±0,01	1,07±0,01	1,49±0,02	5,56± 0,08
Sakarya	5	1,06-1,13	0,44-0,52	0,41-0,44	0,30-0,34	0,66-0,72	1,03-1,08	1,45-1,55	5,39-5,74
		0,99±0,01	0,41±0,01	0,37±0,01	0,27±0,00	0,58±0,01	0,93±0,01	1,31±0,02	4,87± 0,07
Düzce	9	0,96-1,04	0,38-0,44	0,33-0,44	0,26-0,29	0,55-0,63	0,90-1,01	1,25-1,40	4,70-5,21
		1,14±0,01	0,47±0,01	0,43±0,00	0,32±0,01	0,69±0,01	1,05±0,01	1,46±0,01	5,55± 0,05
Artvin	10	1,06-1,18	0,44-0,49	0,40-0,44	0,28-0,34	0,66-0,73	0,99-1,08	1,40-1,50	5,28-5,69
		1,16±0,01	0,46±0,00	0,41±0,02	0,32±0,00	0,68±0,00	1,08±0,01	1,50±0,01	5,61± 0,04
Trabzon	9	1,14-1,19	0,45-0,48	0,39-0,44	0,31-0,34	0,66-0,70	1,06-1,12	1,46-1,57	5,50-5,79
		0,96±0,01	0,38±0,01	0,35±0,01	0,26±0,00	0,56±0,01	0,90±0,01	1,26±0,01	4,66± 0,06
Ordu	9	0,89-1,00	0,34-0,41	0,32-0,37	0,25-0,28	0,52-0,58	0,83-0,95	1,19-1,30	4,39-4,84
		0,97±0,01	0,39±0,00	0,37±0,00	0,28±0,00	0,58±0,00	0,94±0,01	1,31±0,01	4,85± 0,04
Isparta	9	0,92-1,01	0,38-0,41	0,36-0,39	0,27-0,29	0,56-0,60	0,90-0,98	1,25-1,37	4,72-4,92
		1,01±0,01	0,43±0,00	0,39±0,01	0,29±0,00	0,63±0,01	1,00±0,01	1,39±0,01	5,13± 0,06
Muğla	8	0,97-1,07	0,41-0,45	0,33-0,41	0,26-0,30	0,60-0,66	0,95-1,05	1,35-1,42	5.00-5,35
		1,01±0,01	0,42±0,01	0,37±0,01	0,29±0,00	0,59±0,01	0,94±0,01	1,33±0,02	4,94± 0,06
Gaziantep	9	0,97-1,07	0,40-0,46	0,34-0,40	0,28-0,29	0,54-0,62	0,90-1,01	1,27-1,46	4,76-5,29
		1,02±0,03	0,43±0,01	0,38±0,01	0,28±0,01	0,61±0,02	0,98±0,02	1,36±0,02	5,06± 0,11
Hatay	7	0,94-1,14	0,41-0,47	0,35-0,43	0,26-0,31	0,56-0,67	0,93-1,04	1,29-1,47	4,81-5,53
		1,00±0,01	0,43±0,01	0,39±0,01	0,31±0,00	0,62±0,01	1,00±0,01	1,41±0,00	5,17± 0,04
Kilis	3	0,99-1,02	0,42-0,45	0,38-0,40	0,31-0,32	0,61-0,64	0,99-1,01	1,40-1,41	5,14-5,21
		0,99±0,01	0,40±0,01	0,36±0,01	0,27±0,00	0,56±0,01	0,90±0,01	1,29±0,01	4,77± 0,06
Kahramanmaraş	8	0,95-1,06	0,37-0,43	0,33-0,38	0,26-0,29	0,51-0,60	0,85-0,94	1,24-1,37	4,54-5,08
		1,18±0,01	0,49±0,00	0,44±0,00	0,33±0,00	0,71±0,01	1,08±0,01	1,53±0,01	5,76± 0,04
Ardahan	7	1,16-1,20	0,48-0,50	0,43-0,45	0,32-0,34	0,69-0,73	1,07-1,10	1,49-1,57	5,67-5,88
		1,02±0,01	0,40±0,01	0,38±0,00	0,28±0,01	0,59±0,01	0,93±0,01	1,31±0,01	4,91± 0,05
Kars	8	0,98-1,06	0,38-0,42	0,36-0,40	0,26-0,31	0,56-0,61	0,89-0,98	1,27-1,35	4,79-5,08
		0,91±0,01	0,38±0,01	0,34±0,00	0,26±0,00	0,53±0,01	0,87±0,01	1,22±0,01	4,51± 0,05
Van	6	0,87-0,94	0,36-0,40	0,33-0,35	0,25-0,27	0,51-0,55	0,89-0,90	1,19-1,27	4,43-4,58
		0,96±0,01	0,40±0,01	0,36±0,00	0,27±0,00	0,56±0,01	0,89±0,01	1,29±0,01	4,74± 0,05
Hakkâri	8	0,92-0,99	0,37-0,43	0,34-0,39	0,26-0,28	0,52-0,59	0,86-0,92	1,24-1,31	4,54-4,85
Average	143	1,04±0,01	0,43±0,01	0,39±0,01	0,29±0,00	0,62±0,01	0,98±0,01	1,38±0,01	5,12± 0,04
		0,99-1,08	0,40-0,45	0,36-0,42	0,28-0,31	0,59-0,65	0,94-1,02	1,33-1,43	4,39-6,08

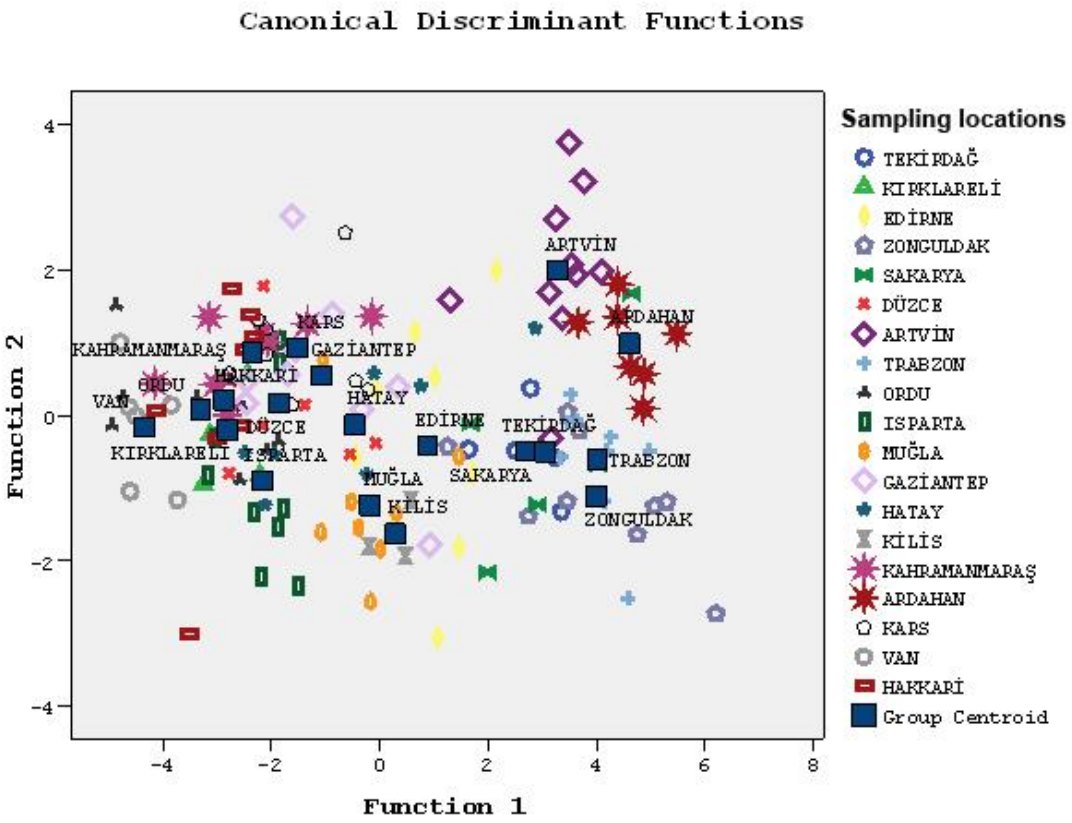

Figure 2. Two dimensional clustering in Canonical Variates Analysis of individuals data from 7 different geographic region.

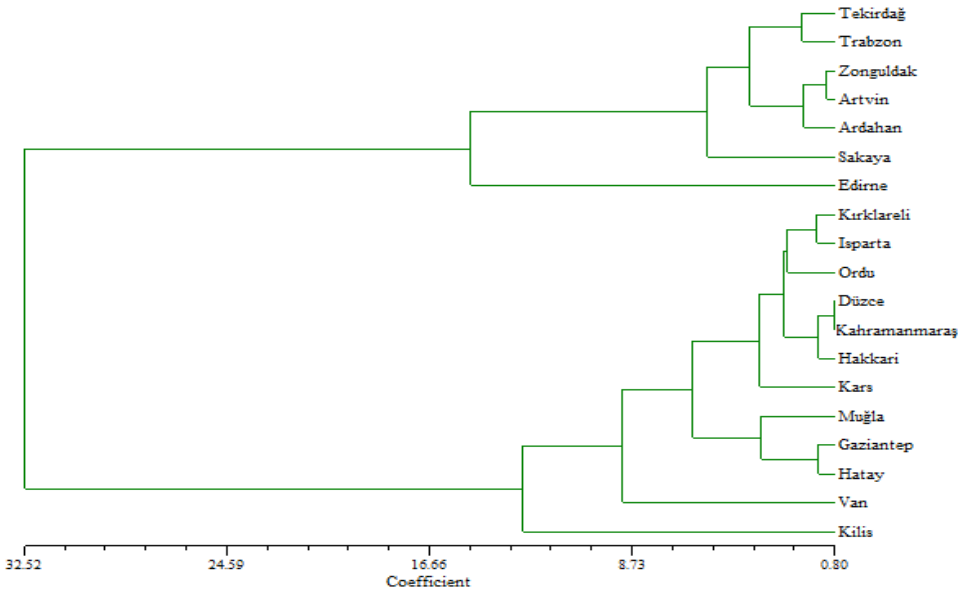

Figure 3. Phylogenetic tree according to UPGMA (Un-weighed Pair Group Method) method based on standardized Euclidean distance

4. Discussion

Morphometric techniques are more advantageous being practical, cheap and no requirements of special acknowledge that rather preferred comparison to biochemical and molecular techniques (Sheppard and Smith, 2000). Although gene expressions that are affected largely by environmental conditions cause disadvantages, statistical methods like PCA and DFA apply more than a dozen characters, and morphometric studies are founded more reliable than enzyme locus studies (Rinderer et al., 1990).

The distribution of Anatolian honeybee populations was first studied by Buttel Reepen (1906) in small areas of Aegean and Marmara regions. Employing morphologic characters that divided Türkiye to seven zones by Bodenheimer (1941). Maa (1953) was the first systematist to characterize and named as subgenus of *A. m. anatoliaca* by morphometrics. Adam (1983) examined honeybees in Anatolia and found similar results with Bodenheimer that 4 races with many ecotypes with rich gene sources. Many researchers reviewed through alloenzyme variations of Anatolian honeybees supported the findings of Ruttner (1988) in general (Darendelioglu and Kence, 1992; Kandemir and Kence, 1995; Güler and Kaftanoglu 1999a,b,c; Güler et al. 1999; Kandemir et al.,1995, 2000; Güler et al., 2002).

Both morphometric and alloenyzme studies resulted that five subgenus of *A. mellifera* throughout Türkiye including *A. m. anatoliaca* (Ruttner 1988; Smith et al., 1997; Palmer et. al., 2000; Kandemir et. al., 2006a), *A. m. caucasica* (Ruttner 1988; Smith et. al., 1997; Palmer et al., 2000; Kandemir et al., 2006a), *A. m. carnica* (Bodenheimer 1941; Smith et. al., 1997; Palmer et. al., 2000; Kandemir et. al., 2006a), *A. m. syriaca* (Ruttner 1988; Palmer et al., 2000; Kandemir et. al., 2006 a, b, c), *A. m. meda* (Ruttner 1988).

The area-based geometric morphometric methodology has been used as a tool to investigate the relationship of honeybees in the present study. Area-based geometric morphometrics is a relatively new technique that has generated valuable results in many fields of morphometry (Oettle et al., 2005; Nolte and Sheets 2005; Mendes et al. 2007; Kimmerle et al., 2008; Ogıhara et. al., 2008; Hayes et al., 2007; Francoy et al., 2009a, b).

In our previous traditional morphometric study (Kekeçoğlu, 2007) with the current regional population, the linear regression was found between wing size and geographical location (longitude and latitude), the present analysis enables comparisons of size independent covarians in wing area.

Canonical Variance Analysis (CVA) of shape data revealed strong two main cluster that showed dimensional reduction of variability via canonical variates analysis (CVA) can be appropriate to explore area variability within homogenous samples subspecies (Francoy et al., 2009a, b).

The average area measurements were found 5.5, 5.2, 5.3, 5.3 ve 5.3 mm^2 respectively for *A. m. carnica*, *A. m. macedonica*, *A. m. mellifera*, *A. m. ligustica* ve *A. m. caucasica* subspecies respectively (Uzunov et. al., 2009).

Francoy et al. (2006) reported A7 as 0.92 for African bees and 1.09 for Italian and Carnica bees for the A7 area. As a result of the present study, similar values were found with Tekirdağ, Ordu, Düzce, Isparta Van and Hakkari African bees; while Ardahan, Trabzon and Artvin have higher values. The remaining provinces gave similar values with Carnica and Italian bees.

The area-based geometric morphometric technique can extract subtle differences like these, which can be unexpected or difficult to extract with traditional morphometry. Kekeçolu (2007) found that the specimens from Northeastern honeybee, *A. m. caucasica* formed a strong close cluster with Anatolian honeybee, *A. m. anatoliaca* based on traditional morphometric analysis. However, in this study, in contrast to previous study, the small set of samples from Northeast Anatolia further resolved and formed a distinct cluster that may belong to Caucasican honeybee (Rutner 1988).

5. Conclusion

The valuable results from are-based morphometric were appeared for the description of differences between honey bee populations through North and south of Türkiye. The present results offered an important basis for future comparative studies between honeybee populations, from Georgia and Northeastern part of Türkiye to better clarify the origin and characteristics of Northeastern population of Türkiye.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effect of Addition of Different Gums on The Technological and Rheological Properties of Fish Gelatin

Farklı Gam İlavesinin Balık Jelatinin Teknolojik ve Reolojik Özellikleri Üzerine Etkisi

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Abstract

Technological and rheological properties of fish gelatin (FG) with the addition of different gums (xanthan gum, gellan gum, agar-agar, locust bean gum, carrageenan, guar gum, gum arabic) were determined. Increase in the storage modulus (G′) and loss modulus (G″) was observed with the addition of gums to FG. The elastic structure of FG became stronger and showed a significantly higher gel property (G′>G″). The addition of gum arabic was seen to adversely affect the structure of FG, causing a decrease in gel strength and a more viscous structure. The highest gel strength was achieved with the addition of gellan gum (7.50%). The melting temperatures, gel strength, and consistency index of FG were increased with the addition of all gums, except gum arabic. Addition of 5.00% xanthan gum to FG resulted in an increase in the melting temperature to 15.93°C, which was the highest melting temperature obtained with FG. Similarly, an increase in the melting point was detected with the addition of gellan gum, agar-agar, carrageenan, and carob gum compared to the control. Different hydrocolloids enhanced Kgel, G,G, consistency index, gel strength, and melting temperature of FG. Bloom values for Bovine Gelatin (BG) and FG were 247.16 and 31.29 g, respectively. The bloom value increased to 409.363 with the addition of gellan gum and changed between 8.11-131.08 with the other gums. The water holding capacity (WHC) was found to be 784.36% in BG and 35.14% in FG. The highest WHC among all the mixtures was determined as 232.5% with the addition of 5.00% xanthan gum. The best overall results were obtained with the addition of gellan gum. Gellan gum added to FG could potentially make it suitable for usage in the food industry.

Keywords: Fish gelatin (FG), Gums, Gel strength, Melting point.

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Öz

Farklı gamlar (ksantan gam, gellan gam, agar-agar, keçiboynuzu gam, karagenan, guar gam, gam arabik) ilavesinin balık jelatininin (FG) teknolojik ve reolojik özellikleri üzerine etkisi belirlenmiştir. Balık jelatinine gamların eklenmesiyle birikim modülünde (G′) ve kayıp modülünde (G″) artış tespit edilmiştir. Gam ilavesi ile balık jelatinin elastik yapısı güçlenmiş ve önemli ölçüde daha yüksek bir jel özelliği kazanmıştır (G′>G″). Gam arabik ilavesinin balık jelatininin yapısını olumsuz etkilediği, hem jel mukavemetinde azalmaya hem de daha viskoz bir yapıya neden olduğu tespit edilmiştir. En yüksek jel kuvveti olan 11390.17 Pa değerine % 7.50 gellan gam ilavesiyle ulaşılmıştır. Balık jelatininin erime sıcaklıkları, jel kuvveti ve kıvam indeksi, gam arabik hariç tüm gamların eklenmesiyle artmıştır. Balık jelatinine %5.00 ksantan gam ilave edilmesi, balık jelatini ile elde edilen en yüksek erime sıcaklığı olan 15.93^{o}C'ye erime sıcaklığında bir artışa neden olmuştur. Benzer şekilde gellan gam, agar-agar, karagenan ve keçiboynuzu gam ilavesiyle de kontrole göre erime noktasında artış tespit edilmiştir. Sığır jelatin (BG) ve balık jelatini (FG) için bloom değerleri sırasıyla 247.16 ve 31.29 g olarak tespit edilmiştir. Farklı hidrokolloidler, balık jelatininin Kgel, G',G'', kıvam indeksi, jel kuvveti ve erime sıcaklığını arttırıcı etki göstermiştir. Bloom değeri gellan gam ilavesiyle 409.363 g 'ye yükselirken, diğer gamlarla 8.11 ile 131.08 g arasında değişiklik göstermiştir. Su tutma kapasitesi (WHC) sığır jelatininde %784.36, balık jelatininde ise %35.14 olarak tespit edilmiştir. Tüm karışımlar arasında en yüksek WHC, %5.00 ksantan gam ilavesiyle %232.5 olarak belirlenmiştir. Çalışma kapsamında en iyi sonuçlar gellan gam ilavesiyle elde edilmiştir. Balık jelatinine gellan gam ilavesi ile jelatin gıda endüstrisinde kullanıma uygun hale gelme potansiyeli kazanmaktadır.

Anahtar Kelimeler: Balık jelatini (FG), Gam, Jel kuvveti, Erime sıcaklığı

1. Introduction

The use of gelatin is wide ranging and extensive, giving it a high economic value. Of the approximately 400 thousand tons of gelatin produced worldwide today, 46% is generated from pork, 29.4% from bovine skin, 23.1% from bones and 1.5% from other sources (GME, 2008). According to the Grand View Research reports, the share of gelatin in the world market will exceed 4 billion dollars by 2024 (Karayannakidis and Zotos, 2016). The use of fish skin or bone materials in the production of gelatin has become popular in recent years due to factors such as religious preferences, safety concerns, and economic considerations of pork and bovine gelatin (BG) (Sow and Yang, 2015; Yang and Wang, 2009). For this reason, fish gelatin (FG) has been used as an alternative to bovine and pork gelatin in the food industry (Kaewruang et al., 2014). Since FG does not have the quality parameters of mammalian gelatin, it can't be used directly as an alternative; it needs to be modified with the addition of different processes or additives for use in the food industry. The main advantages of FG are that its source is not associated with the risk of bovine spongiform encephalopathy (BSE) and can be used by diverse religions such as Muslims, Hindus, and Jews. In addition, the main by-product of fish production, which causes waste and pollution, can be utilized to generate the gelatin (Binsi et al., 2009).

Various studies with FG have generally compared its characteristics with pork gelatin. The existing collagen in fish skin was shown to be of a wider variety than mammalian collagen, hydroxyproline and proline contents were lower than mammalian gelatin, and serine and threonine contents were higher in FG (Balian and Bowes, 1977). The higher the proline and hydroxyproline levels, the higher the melting point and gel strength (Karim and Bhat, 2009). It has been reported that the FG yield varies between 6-19%, which is lower than mammalian gelatin. The main quality parameters required for the use of gelatin as an additive in the food industry are high gel strength, as well as suitable melting and gelling temperatures. Various modifications have been reported to increase the weak gel strength of FG. These include mixing high gel strength gelatins with FG, treatment of gelatin with carbohydrates, proteins and different salts, addition of transglutaminase, addition of phenolic compounds, use of cross-linking agents, high pressure, radiation and UV radiation (Avena-Bustillos et al., 2006; Gilsenan and Ross-Murphy, 2000; Lin et al., 2017; Pranoto et al., 2007). The physicochemical properties of FG were reported to be modified by mixing it with food polysaccharides (Sow et al., 2018).

In the current study, gelatin was produced from waste fish skins in order to evaluate the use of this industrial waste material as a source of an economically important food additive. Additionally, changes in the rheological and technical characteristics of the produced FG was determined after the addition of different gums (xanthan gum, gellan gum, agar-agar, carob gum, carrageenan, guar gum, gum arabic).

2. Materials and Methods

2.1. Materials

The skin of rainbow trout (Oncorhynchus mykiss) was used as a source of gelatin. Trout skins were obtained from a trout farm in Çanakkale and stored at -18°C until use. The gums (gellan gum, gum arabic, xanthan gum, carob gum, guar gum, carrageenan, agar-agar) and BG were sourced commercially.

2.2. Methods

2.2.1. Gelatin extraction

Gelatin from fish skin was obtained with a previously reported method (Garcia and del Carmen Guillen, 2003). Frozen fish skins were cut into small pieces with the help of scissors and washed with tap water. The cut skins were immersed in 0.5 M NaCl at 5°C and mixed with a baguette for 5 minutes. The skins were then taken to a beaker containing NaOH (1:5 w/v) and incubated for 40 minutes in a shaking incubator (INFORS) at 20°C at a mixing speed of 180 rpm. Following this, the skins were washed three times with distilled water. Next, the swollen skins were extracted with 0.1 M acetic acid at 50°C at a mixing speed of 180 rpm for 18 hours. The extracted FG was passed through a filter paper and dried at 80°C in an incubator (ERTICK) (Işık, 2018).

2.2.2. Preparation of FG solutions

A total of 7 different gums, including xanthan gum (1), gellan gum (2), agar-agar (3), carob gum (4), carrageenan (5), guar gum (6), gum arabic (7), were evaluated as additives in preliminary experiments. Five

different amounts of each gum corresponding to 0.5, 2.50, 5.00, 7.50 and 10%, to 6.67% (w/v) were added to FG. Prior to the addition of the gums, the dried FG was ground into a more easily soluble form. The solutions were kept at room temperature for 1 hour to hydrate followed by mixing in a shaking incubator at 65°C for 20 minutes at 180 rpm until all the gelatin was dissolved. The prepared solutions were incubated at 4°C for 16-18 hours to form a gel (Cai et al., 2017).

2.2.3. Determination of physicochemical properties of FG

Ash, protein and pH values of the BG and FG samples were determined according to the AOAC (2000) method (AOAC, 2006).

2.2.4. Determination of rheological properties

Small-deformation oscillatory measurements were performed with FG containing 6.67%, w/v of the gum in a controlled-strain rotation rheometer with a peltier system (TA Instruments New Castle, USA). The plate and plate geometry (40 mm diameter of the upper plate), was used with a gap setting of 0.8 mm.

2.2.4.1. Gelation kinetics

To determine gel kinetic parameters, time sweep analysis was performed by using a previously published method (Kuan et al., 2016) with some modifications. Briefly, FG gels were placed on the rheometer plate at a temperature of 24°C. For the product to reach equilibrium, first, the temperature was reduced from 24°C to 4°C at a rate of 1°C/min and a temperature sweep was performed. Time sweep analysis at 4°C for 4000 seconds at a constant frequency of 1 Hz and strain of 1% was performed for samples in which linear viscoelastic regions (LVR) were determined. The data were analyzed using the software supplied with the device. Elasticity and viscosity values were expressed as storage modulus (G′) and the loss modulus (G″), respectively.

2.2.4.2. Determination of gel strength and steady shear experiments

Gel strength is a measure of the stability of the gel against angular frequency, and serves as an indicator of the suitability of the gel for storage. Following the time sweep analysis, the gel strength was determined in the range of 0.1-10 Hz (Anvari & Chung, 2016) at 1% strain with the frequency sweep test (Kuan et al., 2016). For this purpose, compatibility with storage conditions (J') was calculated with the following equation:

$$J' = \frac{G'}{G'^2 + G''^2} \qquad \text{(Eq. 1)}$$

G_N^0 is the indicated gel strength is related to J_N^0. J_N^0 also indicates the frequency with the lowest G″ value (Ferry, 1980).

$$G_N^0 = \frac{1}{J_N^0} \qquad \text{(Eq. 2)}$$

Rheological data were tested for compatibility with the Power-Law model. Flow behavior, consistency coefficient (K-Pa.s^n) and flow behavior index (n) values of FG+gum solutions were calculated by using Power-law (Equation 3). The model with the highest coefficient of determination (R^2) was established.

Power law (Ostwald-de Waele equation) model: $\sigma = K(\dot{\gamma})^n$ (Eq. 3)

2.2.4.3. Gelling and melting temperatures

Temperature sweep analysis was performed to determine the gelation and melting temperatures of gelatin solutions. The samples were heated to 10°C, followed by equilibration for about 300 seconds, heating to 50°C at the rate of 1°C/min and then cooling back to 10°C. The crossover point where the storage modulus (G′) was reduced and the loss modulus (G″) was increased was considered as the melting temperature. In the cooling process, the temperature at which G′ and G″ underwent a crossover was considered as the sol-gel transformation or gel formation point.

2.2.4.4. Determination of gel strength (Bloom value)

Bloom value was determined according to a previously described method (Europe, 2000). The FG+gum mixture was dissolved in 105 mL of distilled water and taken into a bloom jar. Gel strength was measured with a

texture analyzer (TA HD plus) at 4°C. Gel force (g) was measured as the force required for 4 mm penetration into the samples at a penetration rate of 1 mm/s.

2.2.5. Texture profile analysis

The hardness properties of gelatin were determined using a 36 mm diameter (R/36) probe at 4°C using a texture analyzer (TA HD plus). Test parameters included a test speed of 2 mm/s; Target mode: Compression distance: 5 mm; Duration: 3.0 s; Trigger type: Automatic (force); Trigger force: set to 0.1g (Kuan et al., 2016).

2.2.6. Determination of water holding capacity (WHC) and oil binding capacity (OBC)

WHC and OBC were determined according to the method of (Lin et al., 1974). 1g sample was weighed into a centrifuge tube; 50mL of distilled water and 10mL of corn oil were added to it. After 1 hour of storage at room temperature, the tube was vortexed 4 times for 5 seconds at intervals of 15 minutes. At the end of the process, the tube was centrifuged for 20 minutes at 450 x g. The upper phase was removed and the phase remaining in the centrifuge tube was filtered through a filter paper at an angle of 45 degrees for 30 minutes. The tube and the pellet were weighed and the results were calculated with the following equations:

$$WHC\% = \frac{[Pellet\ weight\ (g) - Gelatin\ weight\ (g)]}{Gelatin\ weight\ (g)} x100 \quad \text{(Eq. 4)}$$

$$OBC\% = \frac{[Pellet\ weight\ (g) - Gelatin\ weight(g)]}{Gelatin\ weight\ (g)} x100 \quad \text{(Eq. 5)}$$

2.2.7. Microstructural properties

Images of gelatin samples were taken with a FEI-QUANTA FEG 250 Scanning Electron Microscope (SEM).

2.2.8. Statistical analysis

The data were analyzed with the JMP 5.0.1.a package program. One-way ANOVA and Tukey's comparison test was used to compare the differences statistically.

3. Results and Discussion

Seven different gums (xanthan gum, gellan gum, agar-agar, carob gum, carrageenan, guar gum, gum arabic) were added to FG in a range of 0.5-10% (w/v). The melting temperature and gel strength were evaluated with rheological analyses in a total of 35 samples (*Table 1*). The ideal gum amount was determined on the basis of the highest gel strength and melting temperature (*Table 2*). As seen in Table 1, the melting points of the samples varied between 14.50-29.74 ºC. While the highest melting point was observed in BG (29.74 ºC), the lowest melting point was found in FG with the addition of 2.50% gellan gum (14.50 ºC). The gel strength of the samples ranged from 749.77-11,390.17 Pa. The highest gel strength was 11390.17 Pa in FG with 7.50% gellan gum added, while the lowest value was 749.77Pa in FG with 5.00% gum arabic added. These findings are in agreement with the commonly accepted 8–25 °C range for fish gelatin to gel (Karim and Bhat, 2009). The incorporation of various hydrocolloids, such as gums, has been reported to enhance the rheological properties of fish gelatin. These hydrocolloids can augment the gel strength and melting degree of the gelatin. This finding is supported by prior research in the field (Haug et al., 2004; Huang et al., 2019).

The pH value of 5 in FG and BG increased to 5.08 only in FG samples with added locust bean gum; all other samples showed a decrease in the pH value. Examples of decreasing pH values were: FG+xanthan gum pH 4.95, FG+gum arabic pH 4.92, FG + carrageenan pH 4.87, FG + guar gum pH 4.86, FG + agar agar pH 4.82 and FG + gellan gum pH 4.78. FG with added gellan gum had the lowest pH value of 4.78 (Table 2). In the literature, it has been reported that the pH value of the produced gelatin changes depending on the extraction processes applied (Songchotikunpan et al., 2008). Depending on the pre-treatment applied to the collagen, different types and properties of gelatin can be obtained including type A and type B gelatin. Type A gelatin has an isoelectric point at pH 6.9, while type B has an isoelectric point at pH 5 (Karim and Bhat, 2009). In addition, pH is one of the important factors affecting the gelling properties of FG (Kaewruang et al., 2014). The gelatin produced in the current study is type B gelatin and may have the potential to be used particularly in acidic foods.

Table 1. Gel strength and melting point values of FG with the addition of gum at different concentrations

Models	Gums	Melting point (ºC)	Gel strength (Pa)	Models	Gums	Melting point (ºC)	Gel strength (Pa)
1	Bovine Gelatin (BG)	29.74±0.005a	5600.87±0.07b	20	FG+5.00% Carob gum	15.51±0.005cde	1455.83±3.18 ghi
2	Fish Gelatin (FG)	15.27±0.011efg	1649.14±0.04ghi	21	FG+7.50% Carob gum	15.52±0.023bcd	2581.93±1.8c
3	FG+0.5% Xanthan Gum	15.22±0.011 efg	1723.57±1.57efg	22	FG+10% Carob gum	15.58±0.021 bcd	1206.43 0.95hij
4	FG+2.50% Xanthan Gum	15.61±0.005bcd	1327.60±2.9 ghi	23	FG+0.5% Carrageenan	15.43±0.017cde	2236.56±22.08def
5	FG+5.00% Xanthan Gum	15.93±0.011b	2658.29±5.64cde	24	FG+2.50% Carrageenan	15.80±0.017bc	1399.635±4.36 ghi
6	FG+7.50% Xanthan Gum	15.50±0.001cde	1684.17±4.25fgh	25	FG+5.00% Carrageenan	15.22±0.017 efg	1046.77±1.28 hij
7	FG+10% Xanthan Gum	15.80±0.046bc	1931.85±4.79efg	26	FG+7.50% Carrageenan	15.71±0.005bcd	1543.205±1.67 ghi
8	FG+0.5% Gellan Gum	14.80±0.017klm	951.89±21.94ij	27	BJ+10% Carrageenan	15.69±0.0175 bcd	3196.742±1.38c
9	FG+2.50% Gellan Gum	14.50±0.003m	2896.58±14.13cd	28	FG+0.5% Guar Gum	14.79±0.005lm	928.82±1.48 ij
10	FG+5.00% Gellan Gum	14.90±0.046ijk	1532.51±2.19 ghi	29	BJ+2.50% Guar Gum	15.00±0.323def	1377.61±2.79 gh
11	FG+7.50% Gellan Gum	15.60±0.017bcd	11390.17±10.17a	30	FG+5.00% Guar Gum	15.22±0.017 efg	1814.04±0.04efg
12	FG+10% Gellan Gum	--		31	FG+7.50% Guar Gum	15.11±0.017fgh	1026.42±0.56hij
13	FG+0.5% Agar Agar	15.10±0.017ghi	1109.88±5.66 hij	32	FG+10% Guar Gum	15.21±0.005 efg	1000.51±14.19 hij
14	FG+2.50% Agar Agar	15.10±0.001 ghi	1681.85±1.37 hij	33	BJ+0.5% Gum Arabic	14.79±0.011lm	1136.54±0.04 hij
15	FG+5.00% Agar Agar	15.20±0.028 efg	2593.06±10.17cde	34	FG+2.50% Gum Arabic	14.89±0.005jkl	934.45±4.04 ij
16	FG+7.50% Agar Agar	15.31±0.005def	3384.56±62.91c	35	FG+5.00% Gum Arabic	15.06±0.028hij	749.77±2.16j
17	FG+10% Agar Agar	15.60±0.017 bcd	5656.14±56.14b	36	FG+7.50% Gum Arabic	14.79±0.005lm	777.44±1.82j
18	FG+0.5% Carob gum	15.60±0.075 bcd	1466.10±66.1 ghi	37	FG+10% Gum Arabic	15.11±0.260def	1438.67±0.07 ghi
19	FG+2.50% Carob gum	15.80±0.011bc	3506.20±6.2c				

*Values in a column followed by different superscript letters are significantly ($p < 0.05$) different (Duncan's test). -: It could not be measured due to conversion to a solid form

Table.2. Physicochemical and technical properties of FG-gum mixtures showing the best rheological properties.

Samples Code	Gelatin-gum mixing ratio (%)	Conc.(%)	pH value	Ash (%)	Water Holding Capacity (%)	Oil Binding Capacity (%)	Degree of Bloom (g)
Control 1	6.67%FG	100%	5±0.02b	6.80±0.02c	35.14±5.105d	146.43±11.975bc	31.29±0.02^{d}
Control 2	6.67% BG	100%	5±0.01b	3.75±0.01$_{1}$	784.36±13.87a	190.87±6.155a	247.16±0.03^{b}
5	6.67% FG+0.033 Xanthan	5.00%	4.95±0.02bc	6.41±0.01d	232.59±16.68b	156.77±13.77bc	9.94±0.02^{h}
11	6.67% FG +0.050 Gellan	7.50%	4.78±0.03f	7.02±0.02b	104.17±1.72c	166.33±4.51b	409.33±0.03^{a}
17	6.67% FG +0.667 Agar Agar	10%	4.82±0.03ef	5.89±0.05f	50.50±14.995d	149.34±7.125bc	131.08±0.03^{c}
19	6.67% FG +0.166 Carob	2.50%	5.08±0.03a	5.79±0.04g	106.82±15.17c	138.83±4.935c	11.52±0.02^{g}
27	6.67% FG +0.667 Carrageenan	10%	4.87±0.01de	8.21±0.01a	99.22±2.92c	140.01±3.83c	19.89±0.01^{e}
30	6.67% FG +0.333 Guar Gum	5.00%	4.86±0.02de	5.69±0.1h	124.36± 4.485c	153.75±0.25bc	8.11±0.01^{i}
37	6.67% FG +0.667 Gum Arabic	10%	4.92±0.02cd	5.99±0.01e	102.19±0.375c	142.89±4.425c	18.76±0.01^{f}

*Values in a column followed by different superscript letters are significantly ($p < 0.05$) different (Duncan's test)

The % ash amounts of FG alone and after the addition of different amounts of gum are shown in *Table 2*. The amount of ash was 6.80% in FG and 3.75% in BG; BG had the lowest ash content of all the samples examined. Among the FG and gum mixtures, FG+carrageenan had the highest ash content with 8.21% while the ash content of the FG+gellan gum mixture was 7.02%. FG+guar gum had the lowest ash content of 5.69% (Muyonga et al., 2004) reported that ash content increased with increasing age in fish; the ash content of older fish skin was higher than that of young fish skins. The ash content of FG was seen to be higher than mammalian gelatin; higher quality FG have a low ash content (Muyonga et al., 2004) reported that a demineralization process applied at the extraction stage can affect the ash content of gelatin. Higher ash content may be seen if the demineralization process is insufficient. It is recommended that high quality gelatin should have an ash content of less than 0.5%, and in food applications, the ash content should be less than 3% (Yearbook, 2019). The FG extracted in the current study as well as the FG-gum mixtures generated had an ash content of more than 3%. This may be decreased further by applying different demineralization processes.

3.1. Rheological properties of FG-gum mixtures

The viscoelastic properties of BG, FG and FG with different gum additions were determined with the frequency sweep test under 1% strain. The frequency-dependent change in G′ and G″ values are shown in *Figure. 1*. The data were adapted to the Power- Law model and the consistency indices (K) and flow indices (n) are given in *Table 3*.

As a general trend, the G′ and G″ values of FG were seen to increase with the addition of gum, suggesting that the elastic structure of FG was strengthened with the addition of gums. The elastic property of the samples was more dominant than the fluidity property and formed a gel-like structure. Among all the FG+gum mixtures, FG+gellan gum showed a significantly higher gel property (G′>G″). The addition of gum arabic negatively affected the structure of FG, causing a decrease in gel strength and a more viscous structure. The results obtained with oscillation tests were compatible with the shear steady flow data. For all samples, G′ appeared to be at least 100 times larger than G″. This is typical of a strong gel system (Yang and Wang, 2009).

Frequency sweep test was performed at 10°C to compare the mechanical strength of FG and FG-gum mixtures (Anvari and Chung, 2016). Frequency scanning under dynamic conditions (in the linear viscoelastic region) showed that both G′ and G″ values increased slightly with increasing frequency in all gum added and control samples (Fig. 1). This property is typical for a concentrated polymer solution (Mei et al., 2012). In addition, G′ was seen to be weakly frequency dependent compared to G″ (Fig. 2), typical of systems with solid-like rheological properties (Zhong and Ikeda, 2012). FG+gellan gum, FG+agar agar and FG+carrageenan showed slower characteristic slopes for the frequency dependence of G′. This suggests the presence of a strong gel structure and shows that gellan gum, agar-agar and carrageenan can strengthen the gel structure of FG. All samples were found to exhibit true gel behavior, regardless of the gum type. The G′ curves for each sample were almost parallel to each other regardless of the oscillation frequency. The G″ was found to be higher than the G″ modulus practically over the entire frequency range. This feature is considered to be typical of systems with a rigid and brittle structure (Lin and Huang, 2003). There was a significant increase in both G′ and G″ with the addition of all gum samples to FG except gum arabic. Addition of hydrocolloids such as gums can increase of G′ and G″ due to intramolecular interactions (Sow et al., 2018).

The flow behavior consistency coefficient (*K*-Pa.s^n) and flow behavior index (n) values of FG+gum solutions are shown in *Table 3*. The K coefficient of the samples varied between 767.54 -12,051 Pa.s^n. The lowest K value was determined as 767.54 Pa.s^n in FG with 5.00% gum arabic added while the highest K value of 12051 Pa.s^n was seen in FG with 7.50% gellan gum added.

The samples with the best K (consistency index) values were determined as FG with addition of 2.50% carob gum, 5.00% xanthan gum, 5.00% guar gum, 7.50% gellan gum, 10% carrageenan and 10% agar-agar, respectively (*Table 3*). The best performing FG+gum mixture was found to be FG+gellan gum; addition of 7.50% gellan gum increased the consistency index and therefore strength of FG to values greater than that obtained with BG. This may have resulted from the contribution of increasing gellan gum concentration and stronger intermolecular interactions to the G′ and G″ values. Similar results were also reported with hydrocolloids such as carrageenan (Haug et al., 2004; Sow et al., 2018). However, the addition of gum arabic negatively affected the rheological properties of FG at all concentrations and decreased the consistency index.

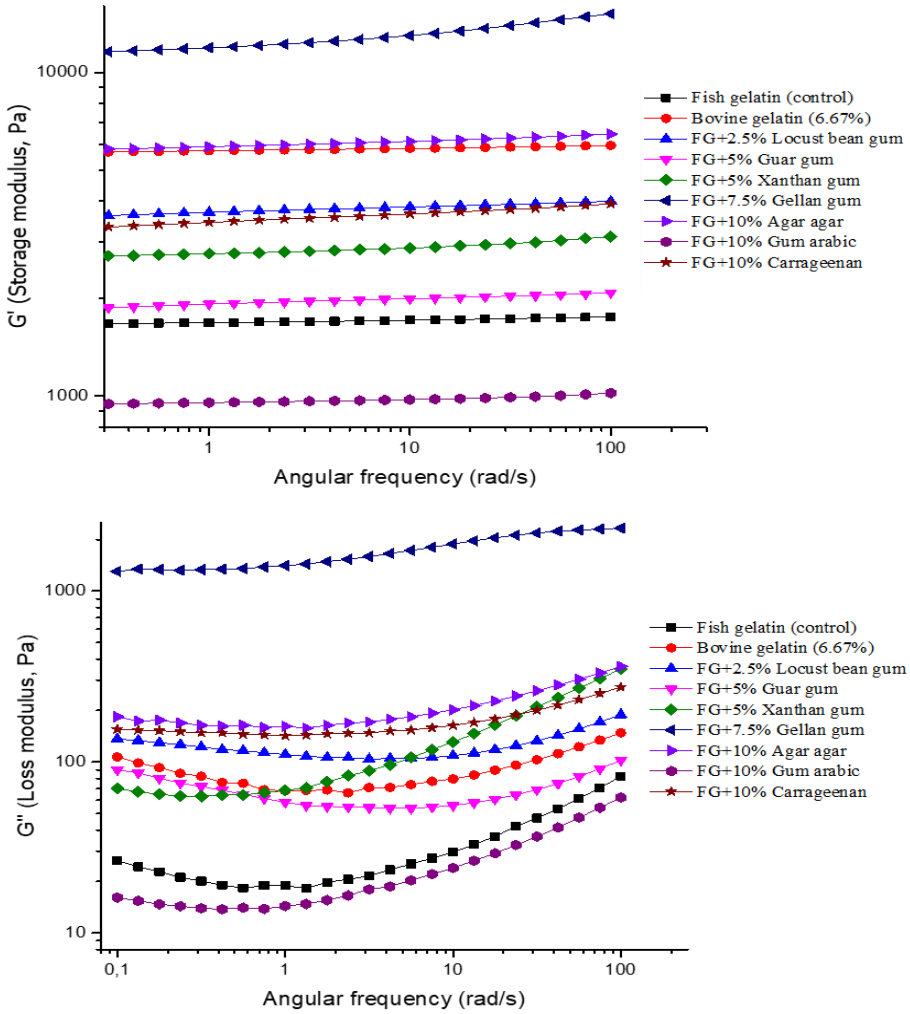

Figure. 1. Variation in G' and G'' values of bovine gelatin (BG), fish gelatin (FG) and FG-gum mixtures as a function of angular velocity.

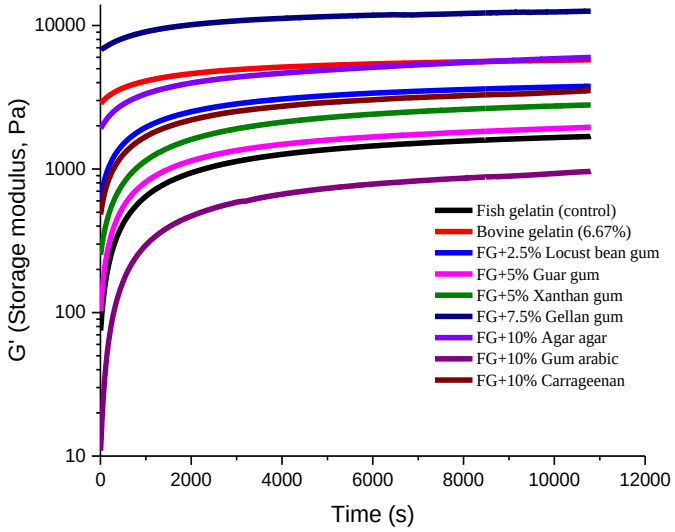

Figure. 2. Time-dependent variation of G' in FG and FG-gum mixtures.

Table.3. Power-Law (PL) model parameters of gum added FG solutions

Samples Code	Samples Name	k (Pa.s^n)	n	R^2	Gelation Kinetics		
					Kgel	C (-)	R^2
Control 1	Fish Gelatin (FG)	1685.1±5.5b	0.0085±0.002a	0.99	378.63±5.29b	1863.9±10.41g	0.96
Control 2	Bovine Gelatin (BG)	5720.9±22.3g	0.0081±0.009a	0.99	630.99±3.93e	112.54±1.09a	0.98
5	FG+Xanthan Gum	2761.3±18.2d	0.0206±0.09b	0.95	604.16±0.92d	1784.7±3.14f	0.96
11	FG+Gellan Gum	12051±1ı	0.0411±0.01e	0.94	1307.1±0.4ı	346.1±0.57b	0.97
17	FG+Agar Agar	5892.7±2.6h	0.018±0.003b	0.99	913.95±2.03h	2786.3±0.28ı	0.97
19	FG+Carob Gum	3683.3±3.9f	0.018±0.004b	0.99	702.08±1.08g	1419.6.7±23.20c	0.98
27	FG+Carrageenan	3429.6±5.4e	0.0282±0.003c	0.99	672.03±0.62f	1614.8±8.44d	0.98
30	FG+Guar Gum	1914.5±4.9c	0.0188±0.002b	0.98	416.2±1.93c	1958.7±3.15h	0.97
37	FG+Gum Arabic	955.87±3.22a	0.0112±0.003a	0.95	330.02±2.81a	1650.6±4.60e	0.96

*Values in a column followed by different superscript letters are significantly ($p < 0.05$) different (Duncan's test)

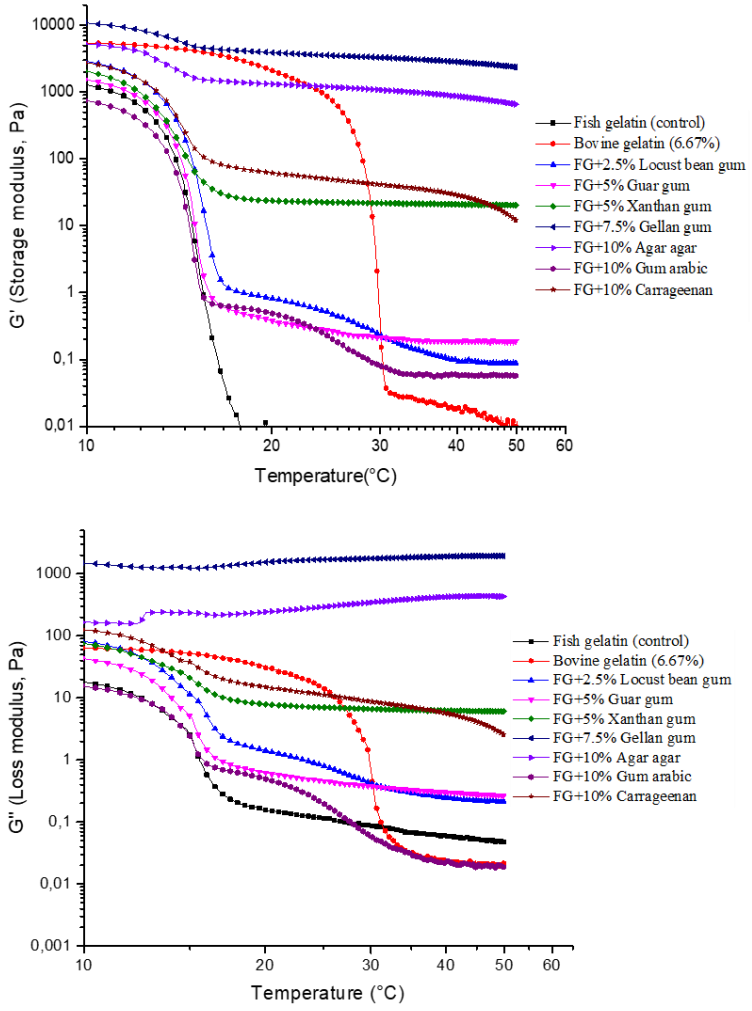

Figure. 3. Variation of G' and G'' values of FG and gum mixtures depending on temperature

The flow behavior index (n) was found to be below 1 in all samples. Elastic properties of all the samples tested were more dominant than viscous properties. The rheological behavior of FG with the addition of 10% agar-agar was found to be similar to that of BG. With the addition of 7.50% gellan gum, the gel structure of FG became approximately 2 times stronger than BG. Evaluating the effects of addition of carrageenan on the structure and rheological properties of FG (Sow et al., 2018). Reported that carrageenan strengthened the rheological properties of FG, corroborating the data from the current study.

As another measure of the rheological properties of FG, BG and FG+gum mixtures, time dependent gelation was determined (*Figure 2*). The G′ value was seen to increase as a function of time when the samples were kept at a constant temperature at 4°C. This indicates that as the residence time increased, the helical structure was increased, reflecting on an increased gel strength. This also indicated that gelation had taken place. The G' value of all samples were seen to increase rapidly for about 1,000 seconds, followed by a gradual plateauing. These data suggest that existing junctions of the fortified gels were constantly reorganized but had the tendency to stabilize over time (Choi and Regenstein, 2000; Kuan et al., 2016).

Gelation kinetic parameters were determined by fitting the experimental data to the logarithmic function model (*Table 3*). The gel strength of FG was increased with the addition of each of the gum samples except gum arabic. This increase was approximately 7 times with the addition of 7.5% gellan gum, giving this sample the highest gel strength. This was followed by agar-agar (5,656.14 Pa), carob gum (3506.20 Pa), carrageenan (3,196.742 Pa), xanthan gum (2,658.29 Pa) and guar gum (1,814.04 Pa). The kgel values of the control FG and BG samples were 378.63 and 630.99 respective; upon addition of the gum samples, the kgel values of FG varied between 007-307.1. Considering the effect of the gums on gelation kinetics and strength of FG, gellan gum was seen to improve Kgel, G″ and gel strength of FG more than the other gums. Similarly, the addition of agar-agar, carrageenan and carob gum improved the structure compared to control FG and BG. The kgel of FG increased approximately 2 times with the addition of carrageenan and locust bean gum, approximately 2.5 times with the addition of agar agar, and approximately 3.5 times with the addition of gellan gum. As a general trend, G′, gel strength and kgel values increased with the increase in the concentration of gum added. These results are in line with those of previously reported studies (Cai et al., 2017; Kuan et al., 2016).

Changes in G′ and G″ values during the heating of gelatin solutions are given in *Figure* 3. The melting temperatures of the samples varied between 14.79°C and 15.93°C. The melting temperature of the control FG and BG samples were 15.11°C and 29.74°C, respectively. A decrease in G' and G" values was observed in all of the samples with the heating process. The melting temperature of FG increased with the addition of xanthan gum, agar agar, gellan gum, carrageenan, locust bean and guar gum, compared to the control FG sample due to the high solute concentration in the gums. An increase in the melting point of FG is important for its use as an alternative to mammalian gelatin in food products. Nonetheless, the 29.74°C melting point of BG could not be reached even at the best highest concentrations of the gums used.

3.2. Gel strength (Bloom Degree)

The bloom degree of the FG samples with different added gums are shown in *Table 2*. The bloom degrees of the control BG and FG samples were 247.16g and 31.29g, respectively. The bloom degree of the FG+gellan gum sample at 409.33g was higher than the control BG sample, followed by FG+agar agar with a bloom value of 131.08g. The lowest bloom value of 9.94g was obtained with the FG+xanthan gum mixture. The gel-forming property of gelatin depends on many factors such as extraction method, temperature, pH, type of raw material used for extraction and additives used during extraction. The cooling temperature and ionic strength of the gelatin sample ban also affect the bloom values (Europe, 2000). The quality of gelatin is measured by gel strength or bloom value and are classified as low (<150), medium (150-220) and high bloom (220-2300) values (Johnston-Banks, 1984). While the gelling strength of commercial gelatins is in the range of 100-300, it is desirable to produce gelatin at 250-260 blooms (Johnston-Banks, 1984). In the current study, samples with low bloom values were obtained, except for the FG+gellan gum mixture and the control BG sample.

3.3. Texture Profile Analysis (TPA)

TPA results of the FG samples with the addition different gums are shown in *Table 4*. The hardness levels of the controls BG and FG were 298.17g and 17.98g, respectively. With the addition of gums to FG, the level of

hardness approached that of BG with hardness of values as high as 231.76g observed in the FG+gellan gum sample. This was followed by FG+agar agar with a hardness value of 104.15g. The hardness values of the other FG+gum samples varied between 16.18 and 42.86g. Considering the degree of elasticity, FG+gellan gum showed the best result with 0.44, followed by BG with 0.399 and then FG+carob gum and FG+gum arabic samples. The degree of elasticity was 0.357 in the control FG samples and the lowest elasticity value was determined as 0.33 in the FG+carrageenan sample.

Evaluation of the parameter gumminess indicated that BG had the highest value of 0.821 while FG+agar agar had the lowest gumminess value of 0.392. The control FG sample had a gumminess value of 0.462. The gumminess value closest to BG was determined in the FG+xanthan gum sample. Evaluation of the parameter chewiness indicated that the best outcome was determined as 97.64 in BG, while the lowest value was measured as 2.81 in FG+guar gum. The control FG sample had a chewiness value of 2.96 suggesting that this parameter was lowered even further with the addition of guar gum. Addition of the other gum samples had an overall positive effect on the chewiness of FG, although the effect was somewhat modest. Among the FG samples with gum addition, the highest chewiness was observed with FG+gellan gum with a value of 48.84. Determination of resilience recovery suggested similar values in FG (0.606) and BG (0.626). The ability of elastic recovery, or resilience, might vary based on the imino acid content of the gel, its molecular weight distribution, and the extraction technique used (Chandra and Shamasundar, 2015).

Table 4. Texture analysis profile of gum added FG solutions

Samples Code	Samples Name	Hardness (g)	Elasticity	Gumminess	Chewiness	Resilience
Control 1	Fish Gelatin (FG)	17.989 ±0.002h	0.357±0.001d	0.462±0.002h	2.969±0.002h	0.606 ± 0.001c
Control 2	Bovine Gelatin (BG)	298.174±0.004a	0.399±0.002b	0.821±0.001a	97.641±0.001a	0.626 ± 0.001b
5	FG+Xanthan Gum	27.123±0.001g	0.349±0.002e	0.656±0.001b	6.207±0.002g	0.537 ± 0.003e
11	FG+Gellan Gum	231.765±0.003b	0.440±0.003a	0.471±0.001g	48.842±0.002b	0.089 ± 0.001ı
17	FG+Agar Agar	104.156±0.001c	0.350±0.002d	0.392±0.002ı	14.563±0.003c	0.128 ± 0.003h
19	FG+Carob Gum	30.758±0.002e	0.390±0.001c	0.601±0.001d	7.206±0.001e	0.586 ± 0.003d
27	FG+Carrageenan	42.863±0.004d	0.330±0.002f	0.521±0.001e	7.374±0.004d	0.276 ± 0.001g
30	FG+Guar Gum	16.183±0.003ı	0.350±0.003d	0.489±0.003f	2.812±0.002ı	0.405 ± 0.001f
37	FG+Gum Arabic	29.103±0.002f	0.390±0.001c	0.615±0.002c	6.979±0.001f	0.634 ± 0.004a

*Values in a column followed by different superscript letters are significantly ($p < 0.05$) different (Duncan's test)

3.4. Water Holding (WHC) and Oil Binding Capacity (OBC)

The water holding and oil binding capacities of control FG and the FG samples with different gum additions are shown in *Table 2*. The sample with the highest WHC was BG with 784.36% followed by FG+xanthan gum with a WHC of 232.59%. The control FG sample had the lowest WHC of 35.14%. Addition of each of the gum samples increased the WHC of FG.

BG had the highest OBC of 190.87% while the lowest OBC was determined in the FG+locust bean gum as 138.83%. Following BG, the highest OBC was observed in the FG+gellan gum mixture of 166.33% (Nurul and Sarbon, 2015). Emphasized that the WHC was related to the amount of hydrophobic amino acids present in the gelatin samples as well as the presence of high amounts of pores and voids in the gel network.

3.5. Microstructural characteristics (SEM)

Microstructures of the control FG and BG samples, as well as FG samples with 7 different gums added were examined by scanning electron microscopy (SEM) (*Figure 4*). SEM images indicated the presence of filamentous-

fibrous structure in the control BG sample (*Figure 4b*) while the control FG sample was more homogeneous and had smaller pores (*Figure 4a*). The FG+carob bean and FG+carrageenan samples were similar in structure to BG, while FG+agar-agar, FG+xanthan gum and FG+gum arabic were similar to FG. FG+guar gum and FG+gellan gum showed a homogeneous and almost smooth structure. These differences in the microstructures could be due to the differences in the chemical composition of the gums. Gums used in this study were obtained from different raw materials, with differences in production methods such as extraction and purification.

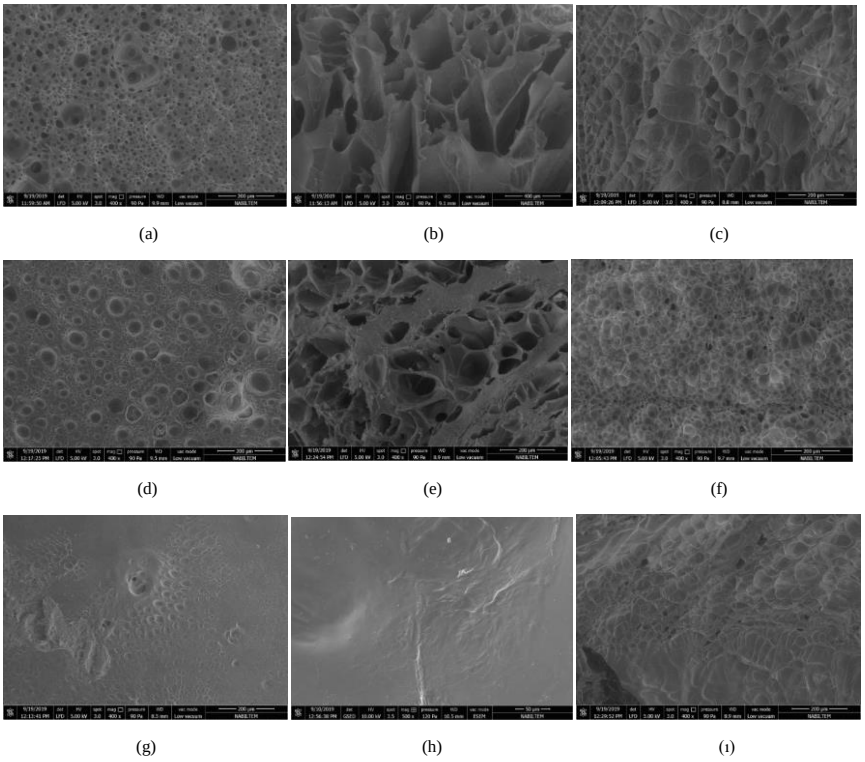

Figure 4. SEM images of bovine gelatin (BG), fish gelatin (FG) and FG with different gums added. (a: FG, b:BG, c:FG+Carob gum, d:FG+Agar agar gum, e: FG+Carrageenan, f: FG+Xanthan gum, g: FG+Guar gum, ı: FG+Gum arabic)

4. Conclusions

Kgel, G′,G″, consistency index, gel strength and melting temperature of FG were increased upon the addition of different hydrocolloids (gellan gum, carrageenan, agar agar, locust bean gum, and xanthan gum). The weaker rheological properties of the control FG samples compared to mammalian gelatin were improved upon addition of the gums. Thus, with the addition of gum, the elastic structure of FG was strengthened and the samples showed higher gel properties. Among the hydrocolloids used in the study, the sample that resembled the characteristics of BG the most was FG+gellan gum. Gum arabic, agar agar and carrageenan, also improved the characteristics of FG; however, the they still fell short of optimal outcomes. FG modified by the addition of gellan gum may have the potential for use in the food industry.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determination of Some Quality Parameters of Buffalo Meat*

Manda Etinin Bazı Kalite Parametrelerinin Belirlenmesi

Birce BARAN[1*], İsmail YILMAZ[2], Ümit GEÇGEL[3]

Abstract

The buffalo (*Bubalus bubalis)* is a cattle that plays an important role in the lives of millions of people in many ways such as milk, meat, cargo, transport, transportation and farm manure in India and other Asian countries. Disease resistance, adaptability to various climatic conditions, better digestible meat of low quality grass-fed, faster growth, and weight gain are essential for buffalo breeders. Buffalo meat is similar to cattle meat in terms of meat composition, quality and sensory characteristics. It has some nutritional advantages such as containing less fat and calories. As a matter of fact, studies on the meat of some other animals such as sheep, lamb and beef, which are among the sources of red meat today, have increased recently. Consumers' interest in buffalo meat is increasing day by day in terms of both the high nutritional value of meat quality and the creation of a new red meat source. In this study, the physicochemical properties of buffalo meats were determined. For this purpose, 20 different Anatolian water buffaloes (7 male and 13 female) grown in the borders of Istanbul/Catalca district were used. The samples were taken from the *Musculus longissimus dorsi (*MLD) part of the animals for the analysis of buffalo meats. Color (L*-brightness, a*-red and green, b*-yellow and blue), moisture content, protein content, fat content, ash content, pH and water activity (aw) of buffalo meat samples were determined. In addition, the fatty acid composition of buffalo meats was determined. The average ash, pH, water activity, moisture, protein and fat ratios of buffalo meats were determined as 2.64%, 5.71, 0.99, 65.60%, 22.28% and 8.65%, respectively. L*, a* and b* values were determined as 42.66, 21.66 and 19.61, respectively. The major fatty acids of buffalo meats were C18:0 (stearic acid) while C18:3 (linolenic acid) was the least abundant fatty acid. The results of this studies suggested that buffalo meat could be considered as a good source of red meat.

Keywords: Buffalo meat quality, chemical properties, fatty acid composition

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Öz

Manda (*Bubalus bubalis*), Hindistan ve diğer Asya ülkelerinde süt, et, yük, taşıma, ulaşım ve çiftlik gübresi gibi birçok yönden milyonlarca insanın hayatında önemli bir rol oynayan, büyük baş hayvandır. Hastalıklara karşı dirençli olması, çeşitli iklim koşullarına uyum sağlaması, düşük kaliteli otla daha iyi sindirilebilirlik özelliği, daha hızlı büyüme ve ağırlık kazanımı manda yetiştiricileri için oldukça önemlidir. Manda eti; etin bileşimi, kalite ve duyusal özellikleri açısından büyükbaş hayvanlara benzerdir ve daha az yağ ve kalori içermesi beslenme açısından oldukça avantajlıdır. Nitekim günümüzde kırmızı et kaynakları arasında yer alan başta koyun, kuzu ve sığır etleri olmak üzerine diğer bazı hayvanların (manda) etleri üzerine de çalışmalar son zamanlarda gittikçe yoğunlaşmaktadır. Tüketiciler açısından hem et kalitesinin besleyici değerinin yüksek olması, hem de yeni bir kırmızı et kaynağı oluşturması açısından manda etine olan ilgi gün geçtikçe artmaktadır. Bu çalışmada manda etlerinin fizikokimyasal özellikleri belirlenmiş ve bu amaçla 7'si erkek, 13'ü dişi olmak üzere İstanbul/Çatalca ilçesi sınırları içerisinde yer alan 20 farklı Anadolu mandası kullanılmıştır. Manda etlerinin analizi için hayvanların *Musculus longissimus dorsi* (MLD) bölümünden örnekler alınmıştır. Alınan manda eti örneklerinde renk (L*-parlaklık, a*-kırmızılık ve yeşillik, b*-sarı ve mavilik), rutubet miktarı, protein oranı, yağ oranı, kül oranı, pH ve su aktivitesi (a_w) analizleri yapılmıştır. Bu analizlere ilave olarak yağları ekstrakte edilen manda etlerinin yağ asitleri bileşimine de bakılmıştır. Analizler sonucunda manda etlerinin ortalama kül, pH, su aktivitesi, nem, protein ve yağ oranları sırasıyla; % 2.64, 5.71, 0.99, % 65.60, % 22.28 ve % 8.65 olarak belirlenmiştir. Etlerin renk değerleri incelendiğinde ise L* değeri 42.66, a* değeri 21.66, b* değeri de ortalama 19.61 olarak tespit edilmiştir. Manda etlerinin yağ asitleri bileşimi incelendiğinde ise hakim (majör) yağ asitinin C18:0 (stearik asit) olduğu tespit edilirken; tüm yağ asitleri arasında en az düzeyde belirlenen yağ asitinin ise C18:3 (linolenik asit) olduğu görülmüştür. Şu ana kadar yapılan çalışmalardan ve bizim yapmış olduğumuz çalışmadan elde edilen sonuçlar dikkate alındığında manda etinin iyi bir kırmızı et kaynağı olacağı belirtilebilir.

Anahtar kelimeler: Manda eti kalitesi, kimyasal özellikler, yağ asitleri kompozisyonu

1. Introduction

Animal husbandry is one of the oldest cultural activities of humankind. Long before animal husbandry, which had only been practiced culturally, people made use of animals in different ways for many years to continue their lives (Şahin, 2015; Mazoyer and Roudart, 2010). According to the records, animal husbandry has been an inseparable component of traditional agriculture for centuries. In Asia, the water buffalos (*Bubalus bubalis*) have played an important role in overall community development due to its contributions to milk, meat, leather and the workforce for agricultural activities. In fact, all of their body parts, including hair and horns, have been utilized. Buffalos have formed a part of the farmers' goods, assets and business. In addition, in some societies, they have been regarded as a reliable "living bank" and an easy "convertible source of money" in order to serve the urgent needs of the rural masses (Nanda and Nakao, 2003).

In recent years, water buffalo breeding has become a significant livestock activity in Turkey, and it is widely used in family-type breeding (Cetinkaya et al., 2011). While the number of water buffalos in our country was 146,000 in 2000, buffalos number decreased to 84,705 in 2007. However in recent years, buffalos number has increased and it reached 185,574 in 2021 (Anonymous, 2022).

The nutritional value and taste of water buffalo meat are similar to beef. Water buffalo meat is slightly darker red color than beef. Carcass fat is yellow-white in cattle, while it is milky white in buffalos (Soysal, 2006). Buffalo meat contains more protein and less cholesterol in comparison to beef. In addition, the low saturated fat content increases the preferability of water buffalo meat (Cetinkaya et al., 2011). The main appealing features of buffalo meat are red color, reduced cholesterol and fat through low intramuscular fat, low connective tissue, high protein content, water holding capacity, myofibrillar fragmentation index and emulsifying capacity (Kandeepan et al., 2013; Yılmaz, 2017).

Among all types of red meat, water buffalo meat was reported to have the lowest total lipid ratio (1.37 g/100 g). Fat content of 1.0% -3.5% was observed in the meat of two-year-old male buffalo calves (Rao and Kowale, 1991). The poor tallow in buffalo meat causes relatively low fat content. Water buffalo meat contains less saturated fat than beef. The energy value of water buffalo meat was found to be 57.22% lower than beef. Low cholesterol content and energy value of buffalo meat (6.8 Kcal/g dry matter) was also reported by Anjaneyulu et al. (2007). Palmitic, stearic, oleic and linoleic acids were reported to be the predominant fatty acids in water buffalo meat phospholipids (Rao and Kowale, 1991). It was also reported that buffalo calves had the most appropriate (n-6)/(n-3) ratio (7.00) compared to beef calves and buffalo cows (Dimov et al., 2012).

Spangero et al. (2004) reported that water buffalo meat was redder and softer than beef. Infascelli et al. (2004) indicated that buffalo meat had lower saturated and higher monounsaturated and polyunsaturated fatty acids comparing to beef. In another study, it was reported that consumption of water buffalo meat contributed to a lower cardiovascular risk profile and had a number of positive effects on health (Giordano et al., 2010). For this reason, studies on the quality features of water buffalo meat can contribute to consumer preference and price improvement of this type of meat.

On the other hand, studies not only on the water buffalo meat but also on the use of various vegetable oil sources, which are obtained by cold press technique, contain substances rich in essential fatty acids and bioactive substances, do not cause quality losses due to not adding animal fat and do not cause harmful effects on cardiovascular health, in meat products instead of using animal fat, which is stated to increase the risk of cardiovascular diseases due to the cholesterol they contain, have also been conducted to a considerable extent (Gecgel et al., 2016), and are still continuing to be conducted.

In determining the quality and quantity of buffalo meat, various factors such as the breed, age, diet, management and welfare of animals as well as environmental conditions are effective (Awan et al., 2014). Studies carried out on the subject show that water buffalo meat is leaner and contains less saturated fat, more protein (11%), less fat (12%), more minerals (10%), less cholesterol (40%) and less calories (55%) compared to beef (Nanda and Nakao, 2003; Borghese, 2010). These results show that buffalo meat is a good source of red meat for those with heart and circulatory system diseases (Kucukkebapci, 2005).

Increasing global demands are forcing the production of economically feasible, high quality and healthier meat and meat products, and forcing to search for an alternative source of meat animal to feed the growing population.

In this study, it is aimed to inform water buffalo breeders and consumers by examining the quality, chemical composition and fatty acid content of buffalo meat, which occupies an important position in the meat industry.

2. Material and Method

20 Anatolian water buffalos, of which 13 (65%) were female and 7 (35%) were male, stocked at the same age and slaughtered when necessary with a carcass weight of 214.00 to 377.40 kg constitute the material of this study. Within the scope of the study, samples were taken from the *Musculus longissimus dorsi* (MLD) muscle of 20 buffalos slaughtered in Catalca district of Istanbul province and brought to the laboratory as soon as possible under cold chain conditions in order to perform analyses. The samples were kept at -18 °C until the analyses were completed.

Analyses of moisture content (%), protein content (Kjeldahl method) (%), fat content (%), ash content (%) and pH value of buffalo meat samples were carried out according to AOAC (1990). In order to determine the Hunter L*, a*, b* colour scales, DP-900 D25-A colorimeter (Hunter Lab Associates, Reston, VA, USA) was used (Marrone et al., 2020). The a_w values of the samples were identified using a Novasina water activity measuring device (Gabriel, 2008).

For fatty acid analysis, the samples kept at -18 °C were melted at +4 °C, and oil extraction was carried out with chloroform: methanol. Afterwards, fatty acid methyl esters were formed from the obtained extract. Methyl esters were prepared according to the method in IUPAC (Anonymous, 1987). In order to determine the fatty acid composition, Shimadzu GC-2010 Plus gas chromatography and DB-23 column (60 m x 0.25 mm and 0.25 µ film thickness) (J&W) were utilized. Helium was used as the carrier gas with a flow rate of 0.1 ml/min. The split ratio was set to be 1:80 and the operating temperatures were set to 230 °C for the injection block, 190 °C for the column and 240 °C for the detector.

Statistical analyses were carried out with SPSS (Statistical Package for Social Sciences) Version 21.0 package program. Mean value, standard deviation and percentage distributions were given as descriptive statistics. Kolomogorov-Smirnov test was applied to find out whether or not the data had a normal distribution. As a result of the related test, the data was found to not have a normal distribution, and as a consequence, non-parametric statistical analysis methods were used. Mann Whitney U test was applied to determine whether there was a difference between parameters according to gender, whereas Spearman's correlation analysis was applied to see the relationship between weight and parameters. The results were evaluated at 95% ($p<0.05$) significance level (Düzgüneş et al., 1987).

3. Results and Discussion

3.1. Physicochemical properties of water buffalo meat

The results of the physicochemical properties of the meat samples are presented in *Table 1*. Accordingly, the average moisture content, aw value, pH, ash content, and protein and fat ratio of buffalo meat samples were found as 65.60%, 0.9973, 5.71, 2.64%, 22.28% and 8.65%, respectively.

3.2. Colour, aw and pH values of water buffalo meat

The average L* value (brightness) of the water buffalo meat samples was found to be 42.66 whereas a* (redness and greenness) and b* value (yellow and blueness) were 21.66 and 19.61, respectively. These values were found to be higher than those reported by Geçgel et al. (2019). The different results were more likely to the diet differences, welfare, and management of the animals, as well as the slaughtering conditions.

The water activity (a_w) values of water buffalo meat samples were between 0.9919 and 0.9999, and the average water activity value was found to be 0.9973 (*Table 1*). The pH values of the buffalo meat samples were between 5.34 and 5.97, and the average pH was found to be 5.71 (*Table 1*). Faustman et al. (2010) reported that the average pH value of water buffalo meat was 5.56 and the average pH value of beef was 5.47. Consequently, the pH values were higher than those (5.03 to 5.46) obtained by Geçgel et al. (2019) in their study on water buffalo meat.

3.3. Moisture, ash, protein and fat values of water buffalo meat sample

The moisture content of water buffalo meat samples were varied between 57.57 and 70.05% (*Table 1*). The results of the variance analysis are presented in *Table 1*. Uğurlutepe (2017) reported that the moisture contents of

Anatolian water buffalo meat samples with low, medium, and high weight were found to be 75.23%, 74.30%, and 74.02%, respectively. The values obtained in this study are lower than the values obtained by Uğurlutepe (2017) whereas they are similar with the values obtained by Geçgel et al. (2019).

The protein ratio of water buffalo meat samples varied between 19.48 and 24.56% and the average protein ratio was found to be 22.58% (*Table 1*). In a study conducted by Infascelli et al. (2005) on water buffalos and Marchigian bulls, the protein ratio of water buffalo meat was reported to be 21.40%, while it was reported to be 22% in Marchigian bull meat. Fonseca et al. (2005) found the protein ratio as 20.52% in their study conducted on Murrah female buffalos. In another study, Malek et al. (2009) reported that the protein ratio of buffalo meat in Bangladesh was 20.90%. Faustman et al. (2010) found the protein ratio of buffalo meat to be 20.39% in their study. In another study conducted on water buffalo meat, the protein ratio was reported to be ranged between 15.12% and 17.65% (Geçgel et al., 2019).

The fat content values of water buffalo meat samples varied between 3.94 and 15.68%, and its average value was found to be 8.65%. The fattiness of water buffalo meat varies based on the diet, breed, and regions where the meat is obtained. The results of variance analysis are presented in *Table 1*.

Table 1. Physicochemical analysis results of buffalo meat

Sample	(Colour)			Water activity(aw)	pH	Moisture(%)	Protein(%)	Fat(%)	Ash(%)
	L*	a*	b*						
1	47.00^{a}	13.66^{d}	18.43^{b}	0.9956	5.86	63.55^{c}	21.51^{a}	12.60^{b}	2.27^{b}
2	32.27^{d}	25.6^{a}	18.68^{b}	0.9931	5.66	62.61^{c}	23.77^{a}	9.66^{c}	3.49^{a}
3	42.04^{b}	24.11^{a}	21.38^{a}	0.9995	5.61	62.59^{c}	22.87^{a}	12.07^{b}	2.25^{b}
4	42.91^{b}	22.13^{a}	21.03^{a}	0.9996	5.65	66.5^{b}	24.59^{a}	4.38^{e}	3.01^{a}
5	40.36^{b}	22.83^{a}	18.62^{b}	0.9948	5.79	68.45^{b}	21.92^{a}	7.22^{d}	3.03^{a}
6	40.86^{b}	19.03^{b}	17.93^{c}	0.9980	5.87	65.77^{c}	19.48^{b}	9.69^{c}	2.60^{b}
7	42.94^{b}	22.53^{a}	20.21^{a}	0.9950	5.62	67.76^{b}	22.28^{a}	5.24^{e}	3.07^{a}
8	47.08^{a}	20.92^{b}	20.31^{a}	0.9927	5.75	61.59^{c}	21.15^{a}	11.93^{b}	2.54^{b}
9	48.86^{a}	23.27^{a}	21.90^{a}	0.9919	5.58	57.57^{d}	24.23^{a}	14.26^{a}	2.26^{b}
10	44.89^{b}	21.04^{a}	20.32^{a}	0.9980	5.70	68.13^{b}	21.23^{a}	8.53^{c}	2.85^{b}
11	43.83^{b}	17.76^{c}	17.39^{c}	0.9999	5.79	61.45^{c}	19.6^{b}	15.68^{a}	2.41^{b}
12	45.1^{a}	20.47^{b}	20.09^{a}	0.9988	5.64	70.06^{a}	21.83^{a}	3.94^{e}	3.18^{a}
13	40.94^{b}	17.65^{c}	17.66^{c}	0.9977	5.34	67.36^{b}	22.15^{a}	4.96^{e}	2.70^{b}
14	42.44^{b}	23.03^{a}	20.43^{a}	0.9999	5.79	64.77^{c}	21.92^{a}	9.16^{c}	2.46^{b}
15	37.35^{c}	26.47^{a}	19.26^{a}	0.9999	5.79	67.63^{b}	21.67^{a}	5.04^{e}	2.87^{b}
16	42.19^{b}	25.14^{a}	20.92^{a}	0.9985	5.97	62.14^{c}	23.38^{a}	8.87^{c}	2.35^{b}
17	46.91^{a}	20.93^{b}	19.81^{a}	0.9972	5.69	66.73^{b}	23.36^{a}	4.99^{e}	2.65^{b}
18	48.21^{a}	20.84^{b}	20.72^{a}	0.9968	5.76	66.26^{b}	23.41^{a}	5.88^{e}	2.59^{b}
19	38.96^{c}	22.31^{a}	18.50^{b}	0.9989	5.68	65.84^{c}	20.89^{b}	11.72^{b}	1.47^{c}
20	38.13^{c}	23.57^{a}	18.67^{b}	0.9999	5.75	64.29^{c}	24.56^{a}	7.29^{d}	2.91^{b}

Means within the same column with different superscripts are significantly different ($p<0.05$)

3.4. Fatty acid components (%) of water buffalo meat

Average fatty acid ratios in water buffalo meat are shown in *Table 2*. Accordingly, the highest ratio is stearic acid (C18:0) (30.31%) while the lowest ratio is alpha-linolenic acid (C18:3-n3) (0.01%). The fatty acids in red

meat are usually medium and long chain, and consist of approximately 40% saturated, 40% mono-unsaturated, and 2 to 25% poly-unsaturated fatty acids. They are mostly expressed by the length of the carbon chains and the number of double bonds. Oleic acid (C18:1 cis-9), which is the major fatty acid in all types of meat has a ratio of more than 30% among total fatty acids (Chow, 2007).

The fatty acid composition has a significant role in defining meat quality and is often associated with meat flavour as well as nutritional values (Yarali et al., 2014). Examining the fatty acid profile in water buffalo meat samples, palmitic acid (C16:0) is the most abundant saturated fatty acid, followed by stearic acid (C18:0) and myristic acid (C14:0) (*Table 2*). The ratio between n-6 and n-3, which are polyunsaturated (PUFA) fatty acids, is an index mostly used to identify the nutritional value of fats (Santos-Silva et al., 2002). The Health Organization Department recommended that the n-6/n-3 ratio should not exceed 4.0 (Anonymous, 1994). The ratio between n-6 and n-3 PUFA was found to be 15 in water buffalo meat. PUFA:SFA (P:S) ratio is another index used in terms of nutrition and its recommended value in diet is between 0.40 and 0.45 (Anonymous, 1994). Whereas the ratio found in this study is 0.77, which is significantly higher than the recommended level.

Table 2: Fatty acid composition of buffalo meat (%)

Sample	**C:14:0**	**C:16:0**	**C:16:1**	**C:17:0**	**C:17:1**	**C:18:0**	**C:18*t***	**C:18:1*c***	**C:18:2**	**C:18:3**
1	2.03	27.72	0.49	1.16	-	32.3	1.88	32.29	2.13	-
2	1.40	22.06	1.32	1.29	0.32	30.03	2.00	39.53	2.05	-
3	1.73	23.62	1.75	1.12	0.63	22.95	-	45.81	1.90	0.49
4	1.51	20.76	1.66	1.27	0.37	29.58	1.66	41.28	1.91	-
5	1.99	24.36	1.71	1.31	0.37	25.97	1.74	40.86	1.69	-
6	2.39	20.4	5.35	1.52	1.32	31.90	2.27	32.54	2.31	-
7	2.63	24.78	2.18	1.20	-	28.62	1.98	35.00	2.51	1.10
8	1.95	24.45	1.59	1.28	-	32.25	1.35	35.53	1.60	-
9	2.21	29.09	1.62	0.87	-	22.20	0.51	42.96	-	-
10	1.91	24.01	2.27	1.16	0.37	25.09	1.21	42.38	1.60	-
11	1.56	22.45	1.38	1.24	-	29.67	0.60	41.24	1.86	-
12	2.09	25.08	1.02	1.23	-	33.81	-	34.82	1.95	-
13	1.92	24.22	0.80	1.41	-	33.04	-	35.85	1.91	0.88
14	2.15	29.17	0.82	1.14	-	32.58	0.61	32.20	1.33	-
15	-	29.25	-	-	-	22.64	-	48.11	-	-
16	-	27.45	-	-	-	35.38	-	33.85	3.32	-
17	-	28.76	-	-	-	35.34	-	35.90	-	-
18	1.48	22.97	2.61	1.30	-	26.87	0.93	41.41	2.43	-
19	1.44	22.86	0.74	1.48	-	40.48	2.27	28.76	1.97	-
20	-	24.93	-	-	-	35.61	-	35.98	3.48	-
X_{ort}	1.52	23.94	2.37	0.12	0.17	30.32	0.95	37.81	1.80	0.12
Ss (±)	0.84282	6.10400	5.46716	0.53012	0.33183	4.90992	0.87	5.06	0.93412	0.30746

The main fatty acids are found as oleic acid (C18:1) followed by stearic acid (C18:0), palmitic acid (C16:0), palmitoleic acid (C16:1), and linoleic acid (C18: 2), respectively. These fatty acids constitute approximately 95 to 96% of the total fatty acids. C18:1 C18:0 and C16:0 were found as 32.20-48.11%, 22.95-40.48%, and 20.40-29.17%, respectively. Our findings are similar to the values reported by Giuffrida-Mendoza et al. (2015) and Geçgel et al. (2019). The differences in fatty acid composition may vary according to the differences in diet, age and muscle structure of the animals. When the fatty acid composition of the butter made using water buffalo milk was examined by Eser and Inanc (2022), the fatty acids of C16:0 (36.07%), C18:1 (24.19%), C18:0 (9.30%), C14:0

(8.98%) and C4:0 (3.80%) were detected to be at high rates while other fatty acids were found to be at quite low rates.

3.5. Comparison of physicochemical properties of water buffalos based on gender and weight

It was observed that moisture content (%), protein ratio (%), pH value as well as L* and a* values of the male buffalo meat samples were slightly higher than the female buffalos whereas the b* value was lower. There was no significant gender-related difference in terms of related parameters ($p>0.05$) (*Table 3*). Kandeepan et al. (2009) reported that normal values for pH in water buffalo meat ranged from 5.4 to 5.6. In this study, it is possible to state that the pH values of male and female Anatolian water buffalos are at acceptable rates.

The water activity (a_w) value of the buffalo meat samples was found to be between 0.9919 and 0.9999 with an average of 0.9973. The average value of the a_w was very close to each other in terms of both genders. While the ash content of the male buffalo meat samples was lower than that of female buffalo meat samples, the difference between the groups was not significant ($p>0.05$).

It was found that C14:0 and C16:1 ratios of the female buffalo meat samples were significantly higher than the male buffalo meat samples while C18:0 and C18:2n6c ratios were significantly lower ($p<0.05$) (*Table 3*). Most of the previous studies compared carcass fattiness of male and female cattle slaughtered at similar ages (Węglarz, 2010; Daza et al., 2014) reported that females have higher carcas fattiness than males. In a study, it is reported that gender does not have a significant effect on fatty acids (Ekiz et al., 2018). As in this study, Zhang et al. (2010) detected higher rates of myristic acid in male Qinchuan cattle than in females. In many studies, it is found that males have lower intramuscular fat content and higher polyunsaturated fatty acids (PUFA) than females slaughtered at similar age. Hoffman et al. (2005) identified higher rates in males compared to females in terms of PUFA. Hollo et al. (2001) reported that PUFAs were found in higher ratios in male animals than in females except for C20:3 n-6. and the amount of individual saturated fatty acids (SFA) was similar in both genders.

Table 3. Comparison of physicochemical properties of buffalo meats by gender

Characteristics	***Gender***		**p**
	Female	***Male***	
L*	43.04±3.01	41.95±5.86	.721
a*	21.63±2.52	21.72±4.01	.663
b*	19.73±1.44	19.39±1.08	.606
a_w	0.997±0.01	0.997±0.01	.691
pH	5.68±0.13	5.76±0.11	.301
Moisture (%)	65.35±3.58	66.05±3.70	.843
Protein (%)	21.91±1.47	22.98±1.29	.191
Fat (%)	8.62±3.931	8.71±2.85	.956
Ash (%)	2.71±0.31	2.53±0.62	.501
C:14:0	1.85±0.63	0.90±0.87	.009
C:16:0	23.22±7.33	25.25±2.72	.905
C:16:1	3.24±6.66	0.73±0.96	.039
C:17:0	1.13±0.37	0.74±0.70	.578
C:17:1	0.23±0.39	0.04±0.12	.187
C:18:0	28.48±4.24	33.71±4.41	.019
C:18n9t	0.79±0.83	1.42±0.94	.143
C:18:1n9c	39.12±5.11	35.39±4.28	.296
C:18:2n6c	1.58±0.76	2.19±1.14	.035
C:18:3n6	0.17±0.37	0.00±0.00	.181
C:18:3n3	0.01±0.06	0.00±0.00	.463
C:22:1n9	0.04±0.14	0.00±0.00	.463

No significant relationship was observed between the weight of buffalos and the average L*, a* and b* values ($p>0.05$) (*Table 4*). In other words, the weight of the buffalos was not found to be an effective factor on the colour values. In addition, a negative relationship was observed between the weight of buffalos and the moisture content.

However, this relationship was not significant (p>0.05). In addition, as a result of the statistical analysis, no significant relationship was observed between the weight of water buffalos and a_w, and between the weight of water buffalos and the pH value of buffalo meat (p>0.05).

Table 4. The relationship between the weight of buffalo and the characteristics of buffalo meat

Characteristics		**Weight**
L	r	-.114
	p	.631
a	r	.230
	p	.329
b	r	-.104
	p	.663
Moisture	r	-.215
	p	.363
aw	r	.106
	p	.657
pH	r	.316
	p	.175
Ash	r	-.343
	p	.139
Protein	r	.217
	p	.359
Fat	r	.183
	p	.439
C:14:0	r	-.616**
	p	.004
C:16:0	r	.176
	p	.458
C:16:1	r	-.557*
	p	.011
C:17:0	r	-.285
	p	.223
C:17:1	r	-.416
	p	.068
C:18:0	r	.353
	p	.126
C:18:1n9t	r	.170
	p	.474
C:18:1n9c	r	-.211
	p	.372
C:18:2n6c	r	.218
	p	.355
C:18:3n6	r	-.184
	p	.438
C:18:3n3	r	-.020
	p	.934
C:22:1n9	r	-.139
	p	.558

A negative but insignificant relationship was observed between the weight of buffalos and the ash content of buffalo meat (p>0.05) (*Table 4*). In addition, as a result of the statistical analysis, no significant relationship was found between the weight of buffalos and the protein ratio of buffalo meat (p>0.05) (*Table 4*). In a study conducted by Infascelli et al. (2005) on water buffalos and Marchigian bulls, the protein ratio of water buffalo meat was

reported to be 21.40% while it was reported to be 22% in Marchigian bull meat. Fonseca et al. (2005) found the protein ratio as 20.52% in their study conducted on Murrah female buffalos. In another study carried out by Malek et al. (2009) in Bangladesh, it was reported that the protein ratio of buffalo meat was 20.90%. Faustman et al. (2010) found the protein ratio of buffalo meat to be 20.39% in their study. In a study conducted by Uğurlutepe (2017), it was reported that the protein ratio in meat increased as the increase in the weight of buffalos. However, this increase was not significant. Ito et al. (2010) found the protein ratio in Puruna bulls, which were slaughtered at 465.1 kg and 469 kg live weight, to be 22.7% and 22.7%, respectively. In a study conducted by Dimov et al. (2012), it was reported that the protein ratio of young buffalo calves slaughtered at 450 kg live weight was lower than of buffalos slaughtered at 580 to 600 kg live weight.

It was found that a statistically significant ($p<0.05$) negative but highly strong ($r = -.616$) relationship was observed between water buffalo weight and C16:1 while negative but moderately strong ($r = -.557$) relationship was observed between water buffalo weight and C14:0 (*Table4*). In other words, as the weight of water buffalos increases, the ratios of C14:0 and C16:1 decrease significantly. In a study conducted by Uğurlutepe (2017), it was reported that C16:0 and C18:0 fatty acids among the saturated fatty acids were at the highest level in buffalos with low, medium, and high carcass weight.

4. Conclusion

In terms of protein, fat and fatty acids, it was found that the buffalo meat samples had important components for human nutrition. It was observed that gender was important in terms of C14:0, C16:1, C18:0 and C18:2 (n6) fatty acids in the buffalo meat samples examined while live weight was effective on the fatty acids of C14:0 and C16:1. Gender and live weight were not found to be effective in terms of other examined values.

The rapid increase occurring in the world population leads consumers to different protein sources. We are rapidly advancing towards a period in which cultivated animals bred in the traditional style will be much more important in the future. In this sense, the analyzed buffalo meat samples components in a sufficient and balanced, which are important for consumer’s way. Depending on the improvements in people's living standards and education levels, some changes also occur in their consumption habits. Nowadays, humans who have become more conscious about balanced and healthy diets are making efforts in this direction. Considering the results obtained from the studies, it is seen that buffalo meat is very beneficial in terms of nutrition. Taking the findings obtained from previous studies and our study into consideration, it can be said that water buffalo meat is a good source of red meat.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effect of Olive Leaves Hydroalcoholic Extract (*Olea Europaea* L.) and LactoFeed® probiotics on Induced Ascites in Male Broilers

Ebrahim TALEBI[1*], Marjan HAGHIGHAT-JAHROMI[2]

Abstract

The incidence of disease and damage will increase, if environmental control and acceptable management practices are not provided during the rearing period. Ascites affect young broilers with rapid growth, and the most critical factor in causing ascites syndrome is the lack of oxygen in body tissues (hypoxia). This research aimed to investigate the effect of olive leaves hydroalcoholic extract and probiotics (LactoFeed) on experimental ascites caused by levothyroxine in male broiler chickens. The present study was an interventional type, and for its implementation, a single-factor design was used in eight groups with 3 replicates. Data were analyzed based on a one-way analysis of variance. Blood parameters of male chickens were measured after 42 days. Biochemical factors of the blood serum of broilers included AST, ALT, ALT, TSHT, T_4, T_3, Glucose, Cholesterol, Triglyceride, Urea, Uric acid, TP, Albumin, and Globulin. AST, ALT, and ALP levels in the induced ascites group increased by 1.16, 1.35, and 1.16 times, respectively. When the chickens had induced ascites, the levels of all three hormones in the blood serum of broiler chickens increased significantly ($P<0.01$). AST showed a positive and significant correlation with ALT, T_4, and T_3 (0.76, 0.71, and 0.75, respectively). But there was a very significant negative correlation between TP (-0.86) and albumin (-0.84). T4 had a positive and significant correlation with T_3, glucose, cholesterol, TG, and urea. The olive extract had a positive effect on induced ascites and improved poultry performance. Probiotics, also, had a positive effect on the treatment of birds induced ascites.

Keywords: Olive leaves extract, Probiotic, LactoFeed, Ascites, Levothyroxine.

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1. Introduction

Extensive genetic selection for growth, meat production, and more acceptable feed conversion ratio has led to many physiological modifications (Willems et al., 2013; Zerjal et al., 2021; Esen et al., 2022). One of these changes is the increased incidence of metabolic diseases such as ascites. Ascites occur in unfavorable environmental conditions and unbalanced nutrition (Hossain and Akter, 2022). This complication emerges when there is an imbalance between the amount of available oxygen and the need for oxygen (hypoxia) (Nasrollahi et al., 2016; Li et al., 2022) and through the accumulation of fluid in the ventricular region of the abdomen driven by events related to the need to supply high amounts of oxygen to the tissue (Gamero et al., 2021). Ascites are more typical in fast-growing male broilers reared at high altitudes and are slightly affected by cold stress (Özkan et al., 2010). However, infectious agents such as *Aspergillosis*, *E. coli*, and bronchitis virus also induce ascites syndrome (Julian, 2000), which is known as a complication of right ventricular dysfunction (Martínez et al., 2021).

Before the bird shows clear symptoms of ascites, which include increased pulmonary blood pressure, pericardial fluid retention, hypertrophy, and dilation of the heart, especially the right ventricle, specific blood, and anatomical changes occur in the body (Hossain and Akter, 2022; Li et al., 2022). Hematocrit, hemoglobin, and red blood cell count are significantly increased in birds with ascites (Luger et al., 2003; Li et al., 2022). The lack of oxygen in birds stimulates the kidneys to produce erythropoietin, which stimulates the production of red blood cells in the bone marrow. This leads to an increase in hematocrit, which leads to an increase in blood viscosity (Hossain and Akter, 2022). In some special conditions, such as when there is a lack of oxygen, increasing the activity of thyroid and metabolic hormones, as well as reducing the amount of cellular antioxidants, the portion of radical's production increases greatly (Ma et al., 2004). Finally, free radicals and other active oxygen particles, due to the peroxidation of fat molecules in cell membranes and important organelles inside the cells of vital body tissues cause the destruction of their membranes and the leakage of fluids outside the cells (Khosravinezhad et al., 2017). Therefore, the change in the antioxidant status of broiler chickens during the development of ascites, characterized by an increase in free radical markers in the damaged tissue, indicates oxidative stress during ascites (Georgieva et al., 2006).

Probiotics are one of the products used in poultry feeding. They are living microorganisms that have many beneficial effects on the microbial population of the gastrointestinal tract and the health of the host. Any change in the microbial flora pattern of the digestive system leads to an increase in the costs related to energy and protein consumption and ultimately increases the bird's oxygen demand (Zheng et al., 2020). Therefore, paying attention to creating a suitable pattern of flora in the digestive system can be effective in reducing the complications related to ascites by improving the immune system and reducing the costs related to oxygen supply (Shimizu et al., 2013). Today, it is known that probiotics, in addition to positive effects on the functioning of the digestive system, such as improving the digestion and absorption of food, and essential minerals, as well as preventing disorders and diseases of the digestive system, reduce symptoms and improve the treatment process of metabolic diseases (Ohashi and Ushida, 2009).

Medicinal plant extracts and essential oils are also used to prevent and help recover birds suffering from ascites. Different parts of medicinal plants are used to stimulate growth, improve immunity, increase digestibility, and prevent and treat diseases in poultry feeding. Among the plants used, we can mention olive tree leaves. Olive leaves contain phenolic compounds, terpenes, fat-soluble compounds, carbohydrates, proteins, minerals, *etc*. (Pereira et al., 2020). They have the highest antioxidant activity and free radical scavenging power among different parts of the olive tree (El and Karakaya, 2009). It has been found that its antioxidant capacity is approximately twice that of green tea and 2.5 times that of vitamin C (Roshanak et al., 2016) and Oleuropein is the most important phenolic compound in olive leaves, which has the capacity of radical adsorption of oxygen ten times as much as green tea with antioxidant and antimicrobial properties (Hayes et al., 2011). This compound has several pharmacological properties, including antioxidant, anti-inflammatory, anti-atherogenic, antimicrobial, and antiviral properties (Omar, 2010).

Due to the limited scientific resources related to the comparison of plant essential oils and the effect of probiotics on ascites, this experiment was performed to investigate the effect of the hydroalcoholic olive extract with probiotics (LactoFeed) on experimental levothyroxine-induced ascites in male broilers.

2. Materials and Methods

Olive leaves were harvested in May 2022. The leaves were identified after being collected at the Medicinal Plants Research Center of Darab Branch, Islamic Azad University. Then they were weighed, washed with distilled water to remove contamination, and spread in the shade. The dried leaves were ground and mixed with 70% ethanol at 40°C. The obtained extract was concentrated with Whatman No. 1 paper and a rotary evaporator (IKA Model RV Basic 05) at 40°C and dried with a freeze dryer (Operon Model FDB 5503). The obtained hydroalcoholic extract was stored away from light at a temperature of 4 °C.

The phenolic amount in the extract was measured by the Folin-Siocalto method and was expressed as mg equivalent of tannic acid per gram of olive leaf extract (Shishehbor et al., 2021; Şahin et al., 2022). Then, different concentrations (50-1000 ppm) were prepared using dried powder, and their antioxidant activity was determined by DPPH and compared with synthetic antioxidants BHA and BHT (Afacan et al., 2014). The net oxidative activity diagram of the extract against the amount of phenolic compounds was determined through Excel and linear equations.

The current experiment was performed at the Darab Branch, Islamic Azad University, Darab, Fars, Iran. In this study, 240 one-day-old male broilers of Ross 308 with an average weight of 47.30±5.00 g were randomly divided into eight experimental groups with three replicates and ten chicks per replication (cage) in a completely randomized design (CRD). Each group had a 4-liter bowl and a separate dining tray.

The experimental treatments included 1) Basal diet (BD), 2) BD+OLE (Olive leaves extract), 3) BD+probiotics, 4) BD+OLE+probiotics 5) Induced ascites+BD, 6) Induced ascites +BD+OLE, 7) Induced ascites+BD+probiotics, 8) Induced ascites+BD+OLE+probiotics. Levothyroxine (a thyroid hormone) was used to induce ascites at a dose of 45 ppm. The concentration of olive leaf extract (OLE) was 150 ppm, and probiotics for ages up to 21 days old and from the age of 21 days to the end (LactoFeed) was 200 and 100 mg/kg, respectively. LactoFeed contained various lactic acid bacteria such as *Lactobacillus acidophilus*, *Lactobacillus casei*, *Bifidobacterium thermophilum*, and *Enterococcus faecium*, which are natural microorganisms found in the digestive system of poultry. A based corn-soybean meal diet was formulated according to Ross 308 requirements for starter (1 to 10 days), grower (11 to 24 days), and finisher periods (25 to 42 days) by UFFDA software (*Table 1*). In all experimental diets, energy, protein, and amino acids were provided at the same level. During the experiment, the light regime was 23 hours and one hour of darkness. The feed was monitored several times during the day and provided to the chickens properly with appropriate drinking water (*ad libitum*).

Table 1. Nutrient contents of basal diet

Feed ingredients	1 to 10 days	11 to 24 days	25 to 42 days
Corn grain	52.55	53.05	54.12
Soybean meal	34.00	34.67	34.86
Corn gluten	5.63	3.00	1.50
Limestone	1.32	1.08	1.04
Dicalcium phosphate	1.76	1.55	1.40
Salt	0.36	0.47	0.42
Threonine	0.10	0.06	0.00
L- Lysine	0.42	0.20	0.00
DL- Methionine	0.32	0.25	0.19
Corn oil lacks antioxidants	3.04	5.17	5.97
Vitamins Mineral premixes[1]	0.50	0.50	0.50
Nutrient composition			
Metabolizable energy (kcal/kg)	3025	3150	3200
Crude protein (%)	23.52	22.00	21.00
Ca (%)	1.05	0.90	0.85
P av. (%)	0.50	0.45	0.42
Methionine + Cystine (%)	1.07	0.95	0.86
Methionine (%)	0.71	0.60	0.53
Lysine (%)	1.44	1.25	1.09
Na (%)	0.16	0.20	0.18

[1]Each kilogram of diet containing vitamin A, 11,000 IU; Vitamin D_3 (Cholecalciferol), 2300 IU; Vitamin E, 121 IU; Vitamin K_3, 2 mg; Vitamin B_{12}, 0.02 mg; Thiamine, 4 mg; Riboflavin; 4 mg; Folic acid, 1 mg; Biotin, 0.03, mg; Pyridoxine 4 mg; Choline chloride, 840 mg; Ethoxyquin, 125 mg; Manganese sulfate, 100 mg; Selenium (sodium selenate), 0.2 mg; Iodine, 1 mg; Copper sulfate, 100 mg; Iron is 50 mg.

At the end of the experiment, two chickens with a weight close to the average of each pen were selected, and approximately 8 ml of blood was taken from each chicken and poured into two test tubes, one containing anticoagulant and the other a simple test tube. The test tubes were stored at a temperature of about 2-4 ° C and transferred to the laboratory in less than 30 minutes, where they were placed in a centrifuge at 3000 rpm for 10 minutes to separate the serum. Samples containing anticoagulants for measuring hemoglobin and hematocrit. The isolated serum samples were kept until the measurement of blood parameters in the freezer at -20 ° C. The dependent variables of blood parameters were included AST, ALT, ALP, TSH, T_4, T_3, glucose, cholesterol, triglyceride, urea, uric acid, total protein, albumin, globulin, RBC, HTC, and body weight, which measured through standard Kits (Pars Azmun, Iran) and a weight scale. The mentioned parameters of blood serum were measured by the standard kits using a spectrophotometer.

The experimental design was a completely randomized design (CRD) and the statistical model of the design was as follows:

$$Y_{ij} = \mu + T_i + e_{ij} \quad \text{(Eq. 1)}$$

Y_{ij}: The observed value, μ: Mean, T_i: treatment effect, e_{ij}: Effect of experimental error

Blood serum enzymes, thyroid hormones, biochemical parameters, RBC, HTC, and body weight were measured based on IU/L, ng/ml, mg/dl, 10^6/μl, percent, and kilogram, respectively. First, the normality of the data was tested through Kolmogorov-Smirnov. The data expressed as a percentage and ratio were first corrected and then subjected to statistical analysis. All statistical analysis were performed using SAS statistical software (version 9.1) with GLM proc and post-hoc Tukey's range test was used to compare the means at the significance level of 0.05.

3. Results and Discussion

The phenolic compounds and DPPH radical inhibition in olive leaf extract was recorded 164.34±0.35 (mg/gram) and 144.35±0.55 (μg/ml), respectively.

The results of statistical analysis comparing the average of AST, ALT, and ALP enzymes are presented in Table 2. The highest concentration of all three enzymes was recorded in ascites chickens (P<0.001). The levels of AST, ALT, and ALP in the induced ascites group increased by 1.16, 1.35, and 1.16 times, respectively, compared to the control group, which showed the highest amount of enzymes compared to other treatments (p<0.001). The induced ascites group that consumed probiotics exhibited the lowest ratio of all three enzymes compared to the group of ascites chickens without treatment. This finding showed the positive effect of probiotic consumption on liver function in chickens with ascites.

Table 2. Comparison between the mean of different enzymes in broiler serum under experimental conditions

Treatment	AST (IU/L)	ALT (IU/L)	ALP (IU/L)
1	20.43±0.49^{c}	15.7±0.40^{d}	88.33±3.06^{e}
2	23.68±1.47^{ab}	17.72±0.54^{cd}	94.00±1.00^{bc}
3	21.1±1.10^{b}	16.37±0.45^{d}	92.33±4.16^{cde}
4	22.83±0.76^{ab}	20.50±0.44^{bc}	89.00±1.00^{de}
5	23.74±0.98^{ab}	21.20±1.65^{b}	102.67±2.52^{a}
6	22.00±0.87^{ab}	22.23±1.26^{b}	101.67±1.53^{abc}
7	22.13±0.42^{ab}	16.89±0.30^{d}	98.00±1.00^{abc}
8	25.10±1.05^{a}	25.4±1.10^{a}	96.67±0.58^{ab}
P-value	<0.001	<0.001	<0.001

[1]: Control, [2]: OLE: Olive leaf extract, [3]: Probiotic, [4]: OLE+probiotics, [5]: Induced ascites, [6]: Induced ascites+OLE, [7]: Induced ascites+probiotics, [8]: Induced ascites+probiotics+OLE, AST: Aspartate transaminase, ALT: Alanine aminotransferase, ALP: Alkaline phosphatase, IU/L: International Unit per Liter, [a-d:] The means with different letters in each column have a significant difference

The occurrence of necrosis or damage to the cell membrane causes the release of AST, ALP, and ALT enzymes into the blood circulation. In the present study, in the group of induced ascites with probiotics, the amount of liver function index enzymes had a significant decrease and showed that probiotics have the most positive effect on liver function in induced ascites and then Olive has a significant positive effect on liver function in induced ascites but less than probiotics. Research showed that probiotics have a positive effect on liver enzymes and improve damaged liver

tissue (Hossain and Akter, 2022; Li et al., 2022). The amount of total fatty acid in the liver decreases due to the consumption of probiotics and they reduce the serum level of ALT. These effects have been associated with a decrease in the activity of TNF-regulated stress kinases. In this study, the serum levels of these enzymes did not increase, especially during the consumption of probiotics, which indicates the absence of liver damage under heat stress due to the consumption of probiotics and the interaction of probiotics and prebiotics. It has been determined that probiotics perform this action through the production of butyric acid and hydrogen, which probably have a stimulating role in the production of antioxidants and the destruction of free radicals (Pereira et al., 2020).

Oleuropein is the most important phenolic compound of OLE and a substance with strong antioxidant and antimicrobial properties. This compound is rarely found in free form in nature. Antioxidant compounds from plant sources are known as oxygen or free radical absorbers. Some molecules, including flavonoids and phenolic compounds, are responsible for the antioxidant properties of natural plant extracts. Flavonoids have a strong antioxidant capacity to inhibit free radicals and end oxidative reactions. Today, the use of plants as an alternative to antibiotics as growth promoters has increased and in poultry feed, various compounds have been studied as alternatives to antibiotics as growth promoters in the production of broiler chickens (El and Karakaya, 2009).

Induced ascites chickens and induced ascites chickens that consumed probiotics and OLE demonstrated the highest levels of serum TSH, T_4, and T_3 hormones (*Table 3*). When the chickens suffered from induced ascites, the level of all three hormones in the blood serum of broiler chickens increased significantly ($P<0.01$). The treatments with OLE were able to significantly decrease TSH, T_4, and T_3 levels compared to other groups.

Table 3 Comparison between means of Thyroid hormone under experimental conditions

Treatment	TSH (ng/ml)	T_4 (ng/ml)	T_3 (ng/ml)
1	26.10 ± 1.61^{c}	7.17 ± 1.05^{c}	1.47 ± 0.21^{c}
2	28.77 ± 1.27^{b}	7.57 ± 0.26^{bc}	1.63 ± 0.31^{c}
3	30.07 ± 1.12^{a}	8.08 ± 0.36^{bc}	1.90 ± 0.21^{abc}
4	27.03 ± 1.12^{b}	9.47 ± 0.57^{bc}	2.13 ± 0.25^{ab}
5	31.10 ± 2.54^{a}	16.88 ± 2.35^{a}	2.50 ± 0.26^{ab}
6	29.80 ± 2.01^{b}	9.43 ± 0.25^{bc}	1.80 ± 0.10^{bc}
7	30.57 ± 0.76^{a}	11.07 ± 0.47^{b}	1.99 ± 0.10^{abc}
8	30.83 ± 0.35^{a}	16.37 ± 1.45^{a}	2.67 ± 0.32^{a}
P-value	0.016	<0.001	<0.001

[1]: Control, [2]: OLE: Olive leaf extract, [3]: Probiotic, [4]: OLE+probiotics, [5]: Induced ascites, [6]: Induced ascites+OLE, [7]: Induced ascites+probiotics, [8]: Induced ascites+probiotics+OLE, TSH: Thyroid stimulating hormone, T_4: Thyroxin, T_3: Triiodothyronine, ng/ml: Nanograms per deciliter, [a-d:] The means with different letters in each column have a significant difference

Thyroid hormones increased in the group receiving OLE and the probiotic group, both individually and in combination. So that the amount of T_4 and T_3 in olives was significantly affected in induced ascites + OLE compared to induced ascites. Research indicated that the plasma concentration of thyroid hormones plays an important role in increasing the metabolism of chickens affected by ascites disease and the prevalence of ascites. The level of thyroid hormone T_3 decreased in chickens with induced ascites that received olive leaf extract (El and Karakaya, 2009). In rats, the administration of triterpenoids isolated from olive leaves for 6 weeks at a dose of 60 mg/kg prevented the development of hypertension and severe atherosclerosis and improved insulin resistance (Manafi et al., 2017).

This disease, also, affected the levels of glucose, cholesterol, triglyceride, urea, uric acid, TP, albumin, and globulin. So that the levels of these biochemical factors in the blood serum of broiler chickens showed a significant increase in chickens with induced ascites compared to other groups ($p<0.001$) (*Table 4*). The use of probiotics and probiotics along with olive leaf extract in both healthy and induced ascites groups caused a significant decrease in the levels of biochemical factors.

The results showed that the amount of albumin and total protein recorded a range of 1.2-1.6, and 3.3-4.2 mg/dl, respectively. The reason for the decrease in albumin and total protein in serum can be attributed to the secretion of high amounts of albumin and total protein in ascites fluid and the decrease in the concentration of ions in the

blood serum. Some studies focused on the ineffectiveness of probiotics on serum lipids (Talebi et al., 2021). However, in this study, the effect of probiotics on serum lipids was significant. Serum protein and albumin are affected in chronic liver diseases and indicate liver damage (Manafi et al., 2017).

Table 4 Comparison between means of some biochemical traits under experimental conditions

Tr	Glucose (mg/dl)	Cho (mg/dl)	TG (mg/dl)	Urea (mg/dl)	UA (mg/dl)	TP (mg/dl)	Al (mg/dl)	Gl (mg/dl)
1	242.1±10.6^{d}	128.7±8.1^{b}	104.7±4.5^{b}	5.3±0.2^{b}	11.7±0.6^{a}	4.2±0.1^{a}	1.6±0.1^{a}	1.7.1^{a}
2	243.5±22.1^{d}	147.3±5.7^{ab}	115.3±5.1^{ab}	5.4±0.2^{b}	10.6±0.6^{ab}	3.6±0.3^{ab}	1.5±0.1^{b}	1.7±0.1^{a}
3	261.1±14.7^{cd}	154.4±9.5^{ab}	116.7±2.1^{ab}	5.7±0.1^{b}	10.6±0.3^{ab}	3.7±0.2^{ab}	1.5±0.1^{ab}	1.5±0.1^{ab}
4	272.7±2.3^{bcd}	161.3±14.8^{a}	122.7±4.5^{a}	5.8±0.1^{b}	10.6±0.5^{ab}	3.5±0.1^{b}	1.4±0.1^{ab}	1.5±0.1^{ab}
5	324.3±3.8^{a}	177.5±5.7^{a}	123.7±2.5^{a}	6.5±0.2^{a}	5.7±4.7^{b}	3.5±0.2^{b}	1.2±0.1^{b}	1.4±0.1^{b}
6	277.4±5.3^{bcd}	154.7±6.0^{ab}	113.3±0.6^{ab}	5.6±0.2^{b}	9.9±0.2^{ab}	3.7±0.1^{ab}	1.5±0.1^{ab}	1.6±0.1^{ab}
7	301.1±26.2^{abc}	175.3±7.5^{a}	124.7±6.4^{a}	5.8±0.1^{b}	10.5±0.4^{ab}	3.7±0.2^{ab}	1.4±0.1^{ab}	1.5±0.1^{ab}
8	321.3±2.5^{ab}	176.3±7.2^{a}	126.3±2.3^{a}	6.8±0.3^{a}	8.1±0.1^{ab}	3.3±0.2^{b}	1.2±0.1^{b}	1.3±0.1^{b}
P-value	<0.001	<0.001	<0.001	<0.001	0.014	0.002	<0.001	<0.001

[1]: Control, [2]: OLE: Olive leaf extract, [3]: Probiotic, [4]: OLE+probiotics, [5]: Induced ascites, [6]: Induced ascites+OLE, [7]: Induced ascites+probiotics, [8]: Induced ascites+probiotics+OLE, TP: Total protein, (mg/dl): milligrams per decilitre, [a-d]: The means with different letters in each column have a significant difference, Tr: Treatment, Cho: Cholesterol, TG: Triglyceride, UA: Uric acid, Al: Albumin, Gl: Globulin

Blood globulin concentration significantly decreased and blood glucose increased ($p<0.001$). These changes are probably due to the increase in food consumption and digestibility of nutrients, glucose retention, increase in gluconeogenesis (through conversion of amino acids to glucose) due to probiotic consumption, decrease in the activity of metabolic enzymes, increase in glycogenolysis and gluconeogenesis. In some studies, it was shown that the serum glucose of broiler chickens was not affected by probiotics, but in the present study, the level of glucose in the blood serum of chickens with induced ascites that consumed probiotics decreased significantly (Manafi et al., 2017; Talebi et al., 2021). Probiotics may cause glucose absorption through insulinotropic polypeptides and the production of glucagon-like peptides. It was reported in the research that probiotic supplements can increase blood serum glucose and albumin in broiler chickens (Pereira et al., 2020; Stanton et al., 2020).

Table 5 Comparison between RBC, HTC, and body weight under experimental conditions

Treatment	RBC (10^6/µl)	HTC (%)	BW (kg)
1	1.82±0.11^{c}	31.99±0.99^{a}	3.33±0.21^{a}
2	1.87±0.06^{c}	31.04±1.06^{ab}	3.17±0.21^{a}
3	2.17±0.12^{bc}	29.20±0.92^{abc}	3.03±0.34^{a}
4	2.27±0.12^{bc}	29.28±0.91^{abc}	3.04±0.07^{a}
5	2.54±0.21^{ab}	26.40±0.78^{bc}	1.93±0.07^{b}
6	2.27±0.15^{abc}	29.57±0.29^{ab}	2.55±0.65^{ab}
7	2.44±0.04^{ab}	28.97±1.01^{bc}	2.30±0.36^{ab}
8	2.67±0.15^{a}	25.03±0.55^{c}	1.87±0.06^{b}
P-value	<0.001	<0.001	<0.001

[1]: Control, [2]: OLE: Olive leaf extract, [3]: Probiotic, [4]: OLE+probiotics, [5]: Induced ascites, [6]: Induced ascites+OLE, [7]: Induced ascites+probiotics, [8]: Induced ascites+probiotics+OLE, RBC: Red blood cell, HTC: Hematocrit, BW: Body weight, (10^6/µl): Million/microliter, [a-d]: The means with different letters in each column have a significant difference.

The intestinal microbial population is involved in the regulation of energy homeostasis and the development of metabolic diseases and insulin resistance in the body's cells. The beneficial effects of probiotics on plasma glucose levels may be due to changes in the microbial composition of the gastrointestinal tract, and the correction of intestinal microflora imbalances by increasing gram-positive bacteria, improving the function of the renal

defense barrier and its immunomodulatory effects. Improve intestinal integrity and simultaneously reduce TLR_4 (Toll-like receptor-4) messaging (Nemati et al., 2017; Li et al., 2022).

The number of RBC in chickens with induced ascites showed a significant increase, and like other measured factors, OLE and probiotics caused its adjustment in sick chickens ($p<0.001$). However, no significant change in the number of red blood cells was observed in healthy chickens with the consumption of OLE and probiotics. HTC percentage was also affected by induced ascites. Thus, the percentage of HTC decreased in sick chickens, but it was compensated by the use of OLE and probiotics (*Table 5*).

The results of the use of probiotics in the diet are very diverse, from no effect on growth indicators to increase yield and increase product quality to promotion. The groups receiving OLE and probiotics showed a positive effect on the amount of total protein in the treatments with ascites. The amount of total protein is measured as a functional factor of the liver. The percentage of hematocrit (HCT) in induced ascites treatment + olive showed a significant increase compared to induce ascites treatment and showed the most positive effect. In terms of weight index, all treatments recorded a significant increase compared to induced ascites treatment. In this study, levothyroxine caused weight loss. Levothyroxine is a precursor of thyroid hormones, and increasing thyroid hormones in the body increases metabolism and increases metabolic energy consumption in treatments receiving levothyroxine (Nemati et al., 2017; Manafi et al., 2017; Li et al., 2022).

AST showed a positive and significant correlation with ALT, T_4, and T_3 (0.76, 0.71, and 0.75, respectively) ($p<0.05$). But there was a very significant negative correlation with TP (-0.86), and Albumin (-0.84). T_4 had a positive and significant correlation with T_3, Glucose, Cholesterol, TG, and Urea. However, it showed a negative correlation with other measured traits (*Table 6*).

Considering that the body weight in this experiment was affected by different treatments and chickens with induced ascites recorded the lowest body weight (1.93±0.07 kg), this trait had a positive and significant correlation with HTC percentage.

Table 6 Correlation between blood parameters under experimental conditions

	ALT	ALP	TSH	T_4	T_3	Glu	Cho	TG	Ur	UA	TP	Al	Glob	RBC	HTC	BW
AST	0.76 *	0.41	0.49	0.71 *	0.75 *	0.62	0.66	0.72 *	0.77 *	-0.66	-0.86 **	-0.84 **	-0.56	0.60	-0.73 *	-0.65
ALT		0.49	0.43	0.71 *	0.76 *	0.68	0.58	0.54	0.76 *	-0.63	-0.74 *	-0.71 *	-0.64	0.72 *	-0.77 *	-0.70 *
ALP			0.82 **	0.62	0.45	0.69	0.63	0.41	0.48	-0.72 *	-0.42	-0.59	-0.51	0.61	-0.55	-0.79 *
TSH				0.70 *	0.63	0.75 *	0.79 *	0.65	0.67	-0.68	-0.62	-0.70 *	-0.73 *	0.75 *	-0.74 *	-0.82 **
T_4					0.94 **	0.95 **	0.83 **	0.74 *	0.97 **	-0.92 **	-0.69	-0.97 **	-0.91 **	0.89 **	-0.95 **	-0.94 **
T_3						0.91 **	0.88 **	0.86 **	0.98 **	-0.81 **	-0.84 **	-0.95 **	-0.95 **	0.92 **	-0.98 **	-0.85 **
Glu							0.92 **	0.81 **	0.91 **	-0.83 **	-0.68	-0.93 **	-0.94 **	0.97 **	-0.93 **	-0.98 **
Cho								0.96 **	0.84 **	-0.72 *	-0.83 **	-0.89 **	-0.90 **	0.94 **	-0.87 **	-0.88 **
TG									0.80 *	-0.59	-0.89 **	-0.85 **	-0.84 **	0.86 **	-0.82 **	-0.74 *
Ur										-0.83 **	-0.78 *	-0.96 **	-0.94 **	0.90 **	-0.99 **	-0.88 **
UA											0.64	0.89 **	0.75 *	-0.73 *	0.82 **	0.82 **
TP												0.81 **	0.73 *	-0.76 *	0.81 *	0.65
Al													0.88 **	-0.87 **	0.94 **	0.90 **
Glo														-0.97 **	0.96 **	0.88 **
RBC															-0.94 **	-0.93 **
HTC																0.90 **

AST: Aspartate transaminase, ALT: Alanine aminotransferase, ALP: Alkaline phosphatase, TSH: Thyroid stimulating hormone, T_4: Thyroxin, T_3: Triiodothyronine, Glu: Glucose, Cho: Cholesterol, TG: Triglyceride, Ur: Urea , UA: Uric acid , TP: Total protein, Al: Albumin, Glo: Globulin, RBC: Red blood cell, HTC: Hematocrit, BW: Body weight, * Significant at $P<0.05$ ** High significant at $P<0.01$.

The liver function index increased in induced ascites compared to the control group. Plasma glucose, cholesterol, triglyceride, globulin and RBC were affected by induced ascites. Liver function factors such as total protein and albumin and blood hematocrit showed a significant decrease, which indicates severe liver damage followed by kidney dysfunction. Blood urea level also increased and blood uric acid level decreased. The basic rations used in this research had the ideal level of protein for chickens, and vegetable food sources were used to estimate the required protein. It seems that the reason for the decrease in blood uric acid levels is the lack of use of animal proteins.

Cholesterol level in induced ascites + olive compared to induced ascites has shown a significant reduction. In people with pulmonary hypertension, the use of olive extract reduced cholesterol, which is consistent with the results of our study (Pereira et al., 2020). The olive extract in male rabbits reduced plasma total cholesterol levels. Other research has shown that the leaves of the olive plant and many medicinal plants contain compounds that have the property of reducing serum lipids.

Triglyceride levels in induction ascites and OLE showed a significant decrease compared to induced ascites treatment. Researchers mention blood parameters as a suitable indicator in the diagnosis of chickens suffering from the challenge of ascites (El and Karakaya, 2009). A positive genetic correlation between hematocrit and ascites. There was a negative relationship between hematocrit and the percentage of oxygen saturation in the blood and the incidence of ascites which was consistent with the results of our research. On the other hand, it, also, affects thyroid function and increases the amount of hormones T_4, T_3, and TSH, which causes weight loss compared to the control group. Weight loss is due to increased basal metabolism and increased energy expenditure. Levothyroxine caused weight loss because levothyroxine is a precursor to thyroid hormones and an increase in thyroid hormones in the body increased metabolism and increased metabolic energy consumption in levothyroxine-receiving treatments.

4. Conclusions

The positive effects of probiotics on the traits examined in this research are quite clear. However, the olive leaf extract is recommended for the prevention of induced ascites due to its reasonable price, availability, and acceptable effectiveness.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Farklı Zamanlarda Ekilen İtalyan Çimi (*Lolium multiflorum* Lam.) ve Tef (*Eragrostis tef* (Zucc) Trotter) Bitkilerinin Ot Verimi ve Kalitesinin Belirlenmesi*

Determination of Yield and Quality of Italian Ryegrass (*Lolium multiflorum* Lam.) and Teff (*Eragrostis tef* (Zucc) Trotter) Sown at Different Times

Betül ACAR[1], Abdullah ÖZKÖSE[2*]

Öz

Bu çalışmada mevcutta ekimi yapılan İtalyan çimi ile yeni bir bitki olan tef bitkisinin farklı zamanlarda ekimlerine göre verim ve kalitelerinin kıyaslanması, özellikle sıcak yaz döneminde gelişimi yavaşlayan İtalyan çimi yerine tef bitkisinin kullanılabilme potansiyeli araştırılmıştır. Bu çalışma Konya koşullarında yazlık olarak farklı zamanlarda ekilen tef ve İtalyan çiminin ot verim ve kalitesinin belirlenmesi amacıyla 2020 yılında yapılmıştır. Deneme tesadüf blokları deneme desenine göre 3 tekerrürlü olarak kurulmuştur. Çalışmada iki İtalyan çimi çeşidi ve iki tef bitkisi çeşidi üç farklı zamanda (1 Mayıs, 1 Haziran ve 1 Temmuz) ekilmiştir. Araştırma sonucunda, tef bitkisinde bitki boyu 75.4 – 84.6 cm, sap kalınlığı 1.70 – 2.15 mm, yeşil ot verimi 5152.2 – 7555.8 kg da^{-1}, kuru ot verimi 1458.6 – 2390.70 kg da^{-1}, kuru madde oranı %25.98 – 32.14, kuru madde verimi 1335.0 – 2176.2 kg da^{-1}, ham protein oranı %6.12 – 8.55, ham protein verimi 108.3 – 149.7 kg da^{-1} arasında; İtalyan çiminde bitki boyu 35.9 – 88.9 cm, sap kalınlığı 2.44 – 3.73 mm, yeşil ot verimi 739.2 – 4604.2 kg da^{-1}, kuru ot verimi 243.3 – 1040.9 kg da^{-1}, kuru madde oranı %14.73–30.13, kuru madde verimi 221.4–952.6 kg da^{-1}, ham protein oranı %9.45 – 11.19 ve ham protein verimi 20.9 – 102.3 kg da^{-1} arasında bulunmuştur. Çalışma sonucunda; Orta Anadolu koşullarında yazlık ekim tarihlerinde, sıcak iklim bitkisi olan tef yeşil ot, kuru ot, kuru madde ve ham protein açısından İtalyan çiminden daha fazla verim vermiştir. İtalyan çimi çeşitlerinin ham protein oranları ise tef çeşitlerinin ham protein oranlarından daha yüksek bulunmuştur. Serin iklim bitkisi olan ve çalışmada kullanılan İtalyan çimi çeşitleri için ise yazlık ekimlerin uygun olmadığı tespit edilmiştir. Tef bitkisi Orta Anadolu koşullarında ekimden 55-65 gün içerisinde ot için biçim olgunluğuna gelmiştir. Tef bitkisi Orta Anadolu koşullarında ikinci ürün olarak 1 Temmuz'da ekildiğinde bile iki kez biçilebilmekte ve iyi bir verim verebilmektedir. Daha fazla tef çeşidi ile benzer çalışmaların yapılması uygun olacaktır.

Anahtar Kelimeler: Ekim zamanı, *Eragrostis tef*, Ham protein, İtalyan çimi, Ot verimi, Tef bitkisi, Yazotu

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Abstract

In this study, the yield and quality of Italian ryegrass and tef plant were compared according to their sowing at different times, and the potential of using tef plant instead of Italian ryegrass, whose development slows down especially during the hot summer period, was revealed. This study was conducted in 2020 to determine the herbage yield and quality of tef and Italian ryegrass sown at different times as summer crops under Konya conditions. The experiment was established according to the randomized block design with 3 replications. Italian ryegrass and two tef plant cultivars were sown at three different times on May 1, June 1 and July 1. As a result of the study, plant height 75.4 – 84.6 cm, stem thickness 1.70 – 2.15 mm, green grass yield 5152.2 – 7555.8 kg da^{-1}, dry grass yield 1458.6 – 2390.7 kg da^{-1}, dry matter rate 25.98% – 32.14%, dry matter yield 1335.0 – 2176.2 kg da^{-1}, crude protein rate 6.12% – 8.55%, crude protein yield 108.3 – 149.7 kg da^{-1} in tef; plant height 35.9 – 88.9 cm, stem thickness 2.44 – 3.73 mm, green grass yield 739.2 – 4604.2 kg da^{-1}, dry grass yield 221.4 – 952.6 kg da^{-1}, dry matter rate 14.73% – 30.13%, dry matter yield 221.4 – 952.6 kg da^{-1}da, crude protein rate 9.45% – 11.19%, crude protein yield 20.9 – 149.7 kg da^{-1} in Italian ryegrass. As a result of the study, tef, which is a warm climate plant, yielded more than Italian ryegrass in terms of green grass, dry matter and crude protein in summer sowing dates under Central Anatolian conditions. The crude protein ratios of Italian ryegrass varieties were higher than the crude protein ratios of tef varieties. It was determined that summer sowing was not suitable for Italian ryegrass cultivars used in the study. In Central Anatolian conditions, Tef plant reaches harvest maturity within 55-65 days after sowing. In Central Anatolian conditions, tef can be mowed twice and give a good yield even when sown on July 1 as a second crop. It would be appropriate to conduct similar studies with more tef varieties.

Keywords: Crude protein, *Eragrostis tef*, Hay yield, Italian ryegrass, Sowing time, Tef plant, Teffgrass

1. Giriş

Hayvancılık işletmelerinde yem maliyetler içerisinde en büyük payı almaktadır. Hayvansal üretimde işletme maliyetinin yaklaşık %70'ini yem masrafları oluşturmaktadır (Moray ve İstanbulluoğlu, 2002). Yem maliyetlerinin yüksekliği işletmeleri olumsuz etkilenmeleridir. Ülkemizde ve dünyada en ucuz kaba yem kaynağı meralardır (Özköse ve ark., 2007). Ülkemizde çayır ve meralarının verimlerinin düşük olması ve hatta bozulmuş olması nedeniyle bu alanlardan beklenen fayda yeterince sağlanamamaktadır (Özköse ve Mülayim, 2013). Hayvansal üretimin verimli bir şekilde sürdürülebilmesi ve arttırılabilmesi için kaba yem ihtiyacının karşılanması önemli bir unsurdur (Burgu ve Mut, 2023). Hayvancılık işletmelerinin kaba yem ihtiyacını karşılamada çayır mera alanlarına ilaveten tarla tarımı içerisinde yetirilen yem bitkileri katkı sağlamaktadır. Son yıllarda yem bitkileri ekim alanı ve verimi artış göstermesine rağmen yeterli değildir. Ülkemizde yem bitkileri tarımını geliştirmek için; mevcut tarımı yapılan yem bitkilerinin verim ve kaliteleri artırılmalıdır. Ayrıca gerek ülke genelinde gerekse bölgesel olarak adapte olabilecek yeni yem bitkisi türleri ile ilgili çalışmaların sayısı hızla artırılmalıdır (Bato ve ark., 2021). Bu yeni türlerden birisi de tef bitkisidir.

Tef (*Eragrostis tef*), Poaceae familyasına ait tropik kökenli bir bitkidir (Ketema, 1997). Türkiye'de yazotu ve tefgrass olarak da bilinen tef bitkisinin gen merkezi Afrika (Etiyopya)'dır (Ketema, 1997; Özköse ve ark., 2022). MÖ 5000 yıllarında Etiyopya'nın yüksek yaylalarında tane ve hayvan yemi olarak yetiştirildiğine dair kanıtlar mevcuttur (Eckhoff ve ark., 1993; NRC, 1996; Ketema, 1997). Ülkemize tef bitkisinin bilinirliği sağlıklı beslenme adına ithal edilen tef tohumları ile olmuştur. Tef tanesi glütensizdir ve çölyak hastalığı olan insanlar için birçok yiyecekte kullanılma potansiyeline sahiptir (Gebremariam ve ark., 2014; Sarı ve Tiryaki, 2018). Ayrıca taneleri zayıflama çayı içinde kullanılmaktadır. Tef ülkemizde insan beslenmesinin yanı sıra son yıllarda alternatif bir yem bitkisi olarak da tanınmaya başlamıştır. Tef bitkisinin otu hayvan beslemesinde kullanılmaktadır. Son yıllarda gerek tanesi için gerekse otu için yetiştiriciliğine Türkiye'de de başlanmıştır (Özköse ve ark., 2022).

Tef bitkisi yüzlek saçak kök sistemine sahiptir (Kaya, 2020). Bitki boyu 20 cm ile 155 cm arasında değişmektedir (Assefa, 2017). Çiçek topluluğu salkım şeklindedir. Tahıllar içerisinde en küçük tohuma (bin tane ağırlığı 0.2-0.4g) sahiptir (NRC, 1996; Ketema, 1997). Tropik ve subtropik iklim bölgelerinin bitkisi olan tef bitkisi fizyolojik olarak C4 bitkisidir. Bitki yüksek sıcaklıklara ve nispeten kurak koşullara dayanıklı bir bitkidir (Minten ve ark., 2013; Miller, 2009). Daha çok tanesi için yetiştiren tef bitkileri erkenci ve tane verimi yüksek iken ot verimi düşüktür. Ancak son yıllarda yem bitkisi olarak geç olgunlaşan ve ot verimi yüksek çeşitler geliştirilmektedir (Miller, 2009).

Sıcak koşullarda hızlı bir şekilde büyüyen Tef bitkisi ekimden kısa bir süre sonra biçim olgunluğuna gelmekte, iklim koşullarına göre çok kez biçilebilmektedir. Türkiye'de yazlık ekilebilme potansiyeline sahiptir. Ancak ülkemizde Tef bitkisi ile ilgili çok fazla çalışma bulunmamaktadır (Özköse ve ark., 2022). Yapılacak bilimsel çalışmalar bitkinin daha fazla tanınmasına ve öneminin anlaşılmasına katkı sağlayacaktır.

Tropik kökenli tef bitkisi yeni ekilmeye başlamış, ülkemizde ve bölgemizde ilgi uyandırmaktadır. Ancak yetiştiriciliği, verim ve kalitesi her bölgemizde belirlenmemiştir. Orta Anadolu Bölgesinde bu bitkinin verim potansiyelinin ve tarımsal uygulamalarının geliştirilmesine ihtiyaç vardır. Yem bitkileri çeşitlerinin farklı iklim, toprak, çevre ve tarımsal uygulamalara göre de verim ve kaliteleri değişmektedir. Bu nedenle Konya bölgesinde Tef bitkisinin verim potansiyelini görmek ve ekim zamanlarına göre verim ve kalitesini belirlemek amacıyla bu çalışma yapılmıştır. Bölge tarımında tef bitkisinin yer alabilmesi birazda mevcut tarımı yapılan bitkilere göre avantajlarının olmasına bağlıdır. Bölgede tarımı yaygınlaşmaya başlayan İtalyan çimi (*Lolium multiflorum* Lam.) (Özköse ve Acar, 2018) ile tef bitkisi birlikte ekilerek verim potansiyelleri kıyaslanacaktır. Çalışmada mevcutta ekimi yapılan İtalyan çimi ile yeni bir bitki olan tef bitkisinin farklı zamanlarda ekimlerine göre verim ve kalitelerini kıyaslamak, özellikle sıcak yaz döneminde gelişimi yavaşlayan İtalyan çimi yerine tef bitkisinin kullanılabilme potansiyelini ortaya koymak amaçlanmıştır. Çalışma ile kaliteli kaba yem açığını kapatmaya katkı sağlamak için yem bitkileri tarımına yeni türlerin, çeşitlerin ve uygulamaların kazandırılması hedeflenmiştir.

2. Materyal ve Metot

Çalışma 2020 yılı yetiştirme sezonunda (Mayıs – Ekim) Selçuk Üniversitesi, Ziraat Fakültesinde Tarla Bitkileri Bölümü Deneme Tarlasında yürütülmüştür. Denemenin yapıldığı alan karasal iklime sahip ve deniz seviyesin yüksekliği yaklaşık 1100 metredir. Çalışmanın yürütüldüğü aylara ilişkin 2020 yıllı ve uzun yıllar ortalamasına ait

iklim verileri *Tablo 1*'de verilmiştir. 2020 yılında denemenin yürütüldüğü aylarda toplam yağış 79.7 mm ortalama sıcaklık 20.9°C ve nispi nem %43 iken uzun yıllar ortalamasında toplam yağış 157.4 mm, ortalama sıcaklık 19 °C ve nispi nem %48.8 olarak gerçekleşmiştir (*Tablo 1*). Deneme yılı uzun yıllar ortalamasına göre daha az yağış almış, daha sıcak ve daha düşük nispi neme sahip olmuştur. Deneme alanının toprakları killi – tınlı bünyeye ve alkalin özelliğe sahiptir. Organik madde miktarı %1.12, EC (µS / cm) = 190, P_2O_5 = 10.58 ppm, K_2O = 242.36 ppm, Na = 67.02 ppm, Ca = 5600 ppm, Zn = 2.13 ppm, Mn = 4.80 ppm, Cu = 0.81 ppm ve Fe = 1.30 ppm olarak tespit edilmiştir (*Tablo 2*).

Tablo 1. Konya İline ait 2020 ve uzun yıllar ortalamasına (UYO) ait iklim verileri (Anonim, 2022).

Table 1. Climate data of Konya Province for 2020 and long-term (LT) average

Aylar	Yağış (mm)		Sıcaklık °C		Nispi Nem (%)	
	2020	U.Y.O. (1930-2021)	2020	U.Y.O. (1930-2021)	2020	U.Y.O. (1930-2021)
Mayıs	43.5	42.51	15.90	15.85	53.6	55.88
Haziran	23.9	25.90	20.30	20.14	47.9	49.11
Temmuz	0.9	7.50	25.50	23.56	36.4	41.21
Ağustos	0.4	6.48	24.20	23.29	31.4	40.84
Eylül	6.9	12.90	22.60	18.81	42.6	46.77
Ekim	4.1	29.78	17.10	12.84	46.4	59.29
Toplam	79.7	125.09				
Ortalama			20.9	19.0	43.0	48.8

Tablo 2. Deneme Alanının Toprak Analiz sonuçları *

*Table 2. Soil analysis results of the trial area**

Toprak Derinliği (cm)	Organik Madde (%)	pH	EC (µS cm^{-1})	P_2O_5 (ppm)	K_2O (ppm)	Na (ppm)
0-30	1.12	7.5	190	10.58	242.36	67.02
Toprak Derinliği (cm)	**Ca (ppm)**	**Zn (ppm)**	**Mn (mg/kg)**	**Cu (ppm)**	**Fe (ppm)**	**Bünye Sınıfı**
0-30	5600	2.13	4.80	0.81	1.30	Killi – Tınlı

*: Toprak analizleri Konya Ticaret Borsası Laboratuvarında yaptırılmıştır.

Çalışmada Konya koşullarında iki tef bitkisi ve iki İtalyan çimi çeşidi 3 farklı zamanda ekilmiş, verim ve kalite özellikleri incelenmiştir. Çalışma tesadüf blokları deneme desenine göre 3 tekerrürlü olarak kurulmuştur. Çalışmada bitki materyali olarak iki tef bitkisi ve iki adet İtalyan çimi çeşidi kullanılmıştır. Tef çeşitleri Rooiberg (Yonca Tarım) (TÇ1) ve Popülasyon (Yiğit Tohum) (TÇ2); İtalyan çimi çeşitleri Excellent (Yonca Tarım) (İÇÇ1) ve Popülasyon (TİGEM) (İÇÇ2) olmuştur. Ekim tarihleri olarak 1 Mayıs, 1 Haziran ve 1 Temmuz olmak üzere üç farklı zaman belirlenmiştir. 1 Mayıs ana ürün, 1 Haziran geç ana ürün, 1 Temmuz ikinci ürün ekim zamanını temsil etmektedir. Çalışma 2020 yılı yetiştirme sezonunda Selçuk Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü deneme tarlasında, laboratuvar analizleri ise Tarla Bitkileri Bölümü Laboratuvarlarında yürütülmüştür. Toprak hazırlığı olarak toprak derince sürülmüştür, sonra diskaro+tırmık kombinasyonu ile ikilenmiştir. Özellikle tef bitkilerinin tohumları çok küçük olduğu için tohum yatağı iyi hazırlanmış ve bastırılmıştır.

Ekim işlemi; markörle açılan sıralara elle yapılmıştır. Ekim derinliği İtalyan çiminde 2-3 cm, tef bitkisinde 1 cm veya daha yüzlek tutulmuştur. Tohumluk miktarı İtalyan çiminde dekara 4 kg, tef bitkisinde ise 2 kg tohum olacak şekilde hesaplanmıştır (Anonim, 2020; Kamacı, 2022). Ekimden sonra toprak merdane ile bastırılmıştır. Parsellerin alanı ekimde 5 x 2 m (0.20 x 10 sıra) = 10 m^2, hasatta ise kenar tesirleri çıkartılarak 4 x 1.6 = 6.4 m^2 olmuştur. Çalışma dört çeşit, üç farklı ekim zamanı ve üç tekerrürlü olarak toplam 36 (4 x 3 x 3) parselden oluşmuştur.

Ekimden önce toprak hazırlığı sırasında dekara 20 kg hesabıyla DAP gübresi verilmiştir. Deneme sulu koşullarda yürütülmüş ve birden fazla biçim yapılmıştır. Son biçim hariç her biçimden sonra 5 kg da^{-1} hesabıyla saf N verilmiştir. Sıra aralarında çıkan yabancı otlar el çapası ile alınmış ayrıca uygun dönemde geniş yapraklı yabancı otlar için herbisit kullanılmıştır. Çıkış için ve gelişme döneminde bitkinin ihtiyacına göre sulama yapılmıştır.

Biçimler salkım veya başak çıkartma döneminde toprak yüzeyinden 5 cm yukarıdan olacak şekilde yapılmıştır. Her biçimden önce bitkisel özellikler, biçimle birlikte verimler, biçimden sonra kuru ot ve laboratuvar analiz sonuçlarına ait veriler elde edilmiştir. Ölçümler, gözlemler ve veriler kenar tesiri dikkate alınarak yapılmıştır. Gözlem ve ölçümler hasattan önce her parselden rastgele seçilen 10 adet bitkide yapılmıştır. Çalışma kapsamında; biçim tarihi, bitki boyu (cm), sap kalınlığı (mm), yeşil ot verimi (kg da^{-1}), kuru ot verimi (kg da^{-1}), kuru madde oranı (%) ve verimi (kg da^{-1}), ham protein oranı (%) ve verimine (kg da^{-1}) ait ölçüm ve analizler yapılmıştır (Akyıldız, 1968; Altın, 1982; Özköse ve ark., 2015; Kaplan ve ark., 2016; Anonim, 2019)

Çalışma kapsamında ekim zamanlarına göre farklı sayıda biçimler yapılmıştır. 1 Mayıs tarihinde ekilen tef ve İtalyan çimleri üçer kez biçilmiştir. 1 Haziran tarihinde ekilen tef çeşitleri üçer kez, İtalyan çimi çeşitleri ise ikişer kez biçilmiştir. 1 Temmuz tarihinde ekilen tef çeşitleri ikişer kez biçilirken İtalyan çimi çeşitleri ise birer kez biçilmiştir. Biçim tarihleri ve biçime kadar geçen gün sayıları *Tablo 3*'te verilmiştir.

Araştırmada elde edilen veriler, tesadüf blokları deneme desenine göre varyans analizine tabi tutulmuştur (Yurtsever, 1984). Denemeye ait veriler Mstat-C bilgisayar programından yararlanılarak analiz edilmiştir. İstatistiki analiz sonucunda önemli farklılık ortaya özelliklerde, ortalamaların karşılaştırılması için LSD testleri uygulanmıştır.

Tablo 3. Çeşitlere göre biçim tarihleri ve biçime kadar geçen gün sayıları

Table 3. Cutting dates and the number of days until the cutting according to cultivars

Ekim Zamanı		1. Biçim		2. Biçim		3. Biçim	
	Çeşit	Tarih	Gün*	Tarih	Gün**	Tarih	Gün***
1 Mayıs	TÇ1	25.07.2020	86	3.09.2020	46	31.10.2020	58
	TÇ2	25.07.2020	86	3.09.2020	46	31.10.2020	58
	İÇÇ1	25.07.2020	86	26.09.2020	63	31.10.2020	35
	İÇÇ2	25.07.2020	86	26.09.2020	63	31.10.2020	35
1 Haziran	TÇ1	8.08.2020	69	26.09.2020	49	31.10.2020	35
	TÇ2	8.08.2020	69	26.09.2020	49	31.10.2020	35
	İÇÇ1	8.08.2020	69	26.09.2020	49		
	İÇÇ2	8.08.2020	69	26.09.2020	49		
1 Temmuz	TÇ1	30.08.2020	61	31.10.2020	62		
	TÇ2	30.08.2020	61	31.10.2020	62		
	İÇÇ1	31.10.2020	113				
	İÇÇ2	31.10.2020	113				

*: Ekimden ilk biçime kadar geçen gün sayısı; **: Birinci biçimden ikici biçime kadar geçen gün sayısı;***: İkinci biçimden üçüncü biçime kadar geçen gün sayısı

3. Araştırma Sonuçları ve Tartışma

3.1. Bitki boyu (cm)

Araştırmada ekim zamanlarının, çeşitlerin ve ekim zamanı x çeşit interaksiyonunun bitki boyuna etkisi istatistiki olarak $p<0.01$ seviyesinde önemli bulunmuştur. Ortalamalar arasındaki farkların önem düzeyini belirlemek için AÖF testi yapılmış, bitki boyuna ilişkin ortalama değerler ve AÖF grupları *Tablo 4*'te verilmiştir.

Ekim zamanları ortalamalarına göre en yüksek bitki boyu 83.5 cm ile 1 Haziran ekiminden elde edilmiş, bunu 1 Mayıs (77.3 cm) ve 1 Temmuz (70.2 cm) ekimleri takip etmiştir (*Tablo 4*). Çeşit ortalamaları arasında en yüksek bitki boyu 82.2 cm ile Tef Çeşit2 de ölçülmüş TÇ1 ve İÇÇ2 ile aynı önemlilik grubunda yer almıştır. En düşük bitki boyu ise 66.5 cm ile İÇÇ1'de ölçülmüştür. Ekim zamanı x çeşit interaksiyonunda bitki boyu 35.9 cm – 88.9 cm arasında değişmiştir. Çeşitlerin ekim zamanlarına tepkileri farklı olmuştur. Özellikle İÇÇ1 yazlık ekimden en olumsuz etkilenen çeşit olmuştur. Tef bitkisi ile çalışan araştırmacılardan Sang-Hoon ve ark. (2015) bitki boyunu 89.3 – 106.7 cm arasında, Gürün ve Geren (2019) 86.3 – 112.3 cm, Geren ve ark. (2019) 44.2 – 58.2 cm, Davison ve ark. (2011) 111.2 – 132.3 cm, (Abebe ve Abebe, 2016) 93 .2 – 101.3 cm, Gürün (2018) 116.5 – 128.3 cm, Tanık (2020) 86.0 – 102.7 cm, Giday ve ark. (2014) 85.7 – 112.3 cm ve Kakabouki ve ark. (2020) 38.42 – 73.1 cm

arasında bulmuştur. İtalyan çimi ile çalışan araştırmacılardan Aktar (2019) bitki boyunu 48.67 – 65.66 cm, Dinç (1995) 113.27 – 129.30 cm, İnce (2000) 86.17 – 96.17 cm, Özdemir (2017) 48.1 – 62.9 cm ve Kamacı (2022) 44.8 – 68.3 cm arasında bulmuşlardır. Çalışma sonuçlarımız araştırmacıların bazılarının sonuçları ile benzer iken, bazılarının sonuçlarından daha düşük veya yüksek olmuştur. Bunun nedenleri arasında bitki boyuna etki eden çeşit, çevre koşulları, sulama, gübreleme, ekim zamanları, ekim sıklığı gibi tarımsal uygulamalardaki farklılıklar olabilir.

Tablo 4. Tef ve İtalyan çimi çeşitlerin bitki boyuna ilişkin ortalama değerler (cm) ve AÖF grupları

Table 4. Aerage values and LSD groups of plant height (cm) of teffgrass and Italian ryegrass cultivars

Çeşit	Ekim Zamanı			Ortalama
	1 Mayıs	1 Haziran	1 Temmuz	
Tef Çeşit1 (TÇ1)	78.2 bc	75.4 bc	79.9 abc	77.8 A
Tef Çeşit2 (TÇ2)	80.9 abc	84.6 abc	78.8 abc	81.4 A
İtalyan Çimi Çeşit1 (İÇÇ1)	74.6 c	88.9 a	35.9 d	66.5 B
İtalyan Çimi Çeşit2 (İÇÇ2)	75.3 c	85.1 abc	85.9 ab	82.1 A
Ortalama	**77.3 B**	**83.5 A**	**70.2 C**	**77.0**

3.2. Sap Kalınlığı (mm)

Araştırmada ekim zamanlarının, çeşitlerin ve ekim zamanı x çeşit interaksiyonunun sap çapına etkisi istatistiki olarak $p<0.01$ seviyesinde önemli bulunmuştur. Ortalamalar arasındaki farkların önem düzeyini belirlemek için AÖF testi yapılmış, sap çapına ilişkin ortalama değerler ve AÖF grupları *Tablo 5*'te verilmiştir.

Tablo 5. Tef ve İtalyan çimi çeşitlerin sap kalınlığına ilişkin ortalama değerler (mm) ve AÖF grupları

Table 5. Aerage values and LSD groups of stem thickness (mm) of teffgrass and Italian ryegrass cultivars

Çeşit	Ekim Zamanı			Ortalama
	1 Mayıs	1 Haziran	1 Temmuz	
Tef Çeşit1 (TÇ1)	1.70 f	1.92 cdef	1.71 f	1.78 B
Tef Çeşit2 (TÇ2)	1.74 ef	2.15 bcdef	1.87 de	1.92 B
İtalyan Çimi Çeşit1 (İÇÇ1)	2.67 b	2.58 bcd	3.73 a	2.99 A
İtalyan Çimi Çeşit2 (İÇÇ2)	2.64 bc	2,44 bcde	3.49 a	2.86 A
Ortalama	**2.19 B**	**2.27 B**	**2.70 A**	**2.39**

Ekim zamanları ortalamalarına göre en yüksek sap kalınlığı 2.70 mm ile 1 Temmuz ekiminden elde edilmiş, bunu 1 Haziran (2.27 mm) ve 1 Mayıs (2.19 mm) ekimleri takip etmiştir (*Tablo 5*). Genel anlamda ekim zamanı geciktikçe sap kalınlığı artış göstermiştir. Çeşit ortalamaları arasında en yüksek sap kalınlığı 2.99 mm ile İtalyan çimi Çeşit1 de ölçülmüş ve İtalyan çimi Çeşit2 (2.86 mm) ile aynı önemlilik grubunda yer almıştır. En düşük sap kalınlığı ise 1.78 mm ile Tef Çeşit1'de ölçülmüş ve Tef Çeşit2 (1.92 mm) ile arasındaki fark istatistiki olarak önemsiz çıkmıştır. Çeşit ortalamalarına baktığımızda Tef çeşitlerinin sapları İtalyan çimi çeşitlerinin saplarından daha ince olduğu açıkça görülmektedir. Ekim zamanı x çeşit interaksiyonunda sap kalınlığı 1.70 mm – 3.73 mm arasında değişmektedir. Çeşitlerin ekim zamanlarına tepkileri farklı olmuştur. İtalyan çimi çeşitlerinin 1 Temmuz ekiminde sap kalınlıkları oldukça yüksek çıkmıştır. Sıcak koşulların İtalyan çiminde sap kalınlığını artırıcı bir etki yaptığını söyleyebiliriz. Tanık (2020) tef bitkisinde sap kalınlığını 1.75 – 1.92 mm arasında belirlemiştir. Araştırma sonuçlarımız Tanık (2020) ile benzerlik göstermiştir. İtalyan çiminde sap kalınlığını Dinç (1995) 2.70 – 3.70 mm ve Kamacı (2022) 2.8 – 3.5 mm, Özköse ve ark. (2015) 1.69 – 3.75 mm, Sever (2021) 2.42 – 3.19 mm arasında bulmuşlardır. Araştırma sonuçlarımız diğer araştırmacıların bulduğu değerler arasında olup benzerlik göstermektedir.

3.3. Yeşil ot verimi

Araştırmada ekim zamanlarının, çeşitlerin ve ekim zamanı x çeşit interaksiyonunun yeşil ot verimine etkisi istatistiki olarak $p<0.01$ seviyesinde önemli bulunmuştur. Ortalamalar arasındaki farkların önem düzeyini belirlemek için AÖF testi yapılmış, yeşil ot verimine ilişkin ortalama değerler ve AÖF grupları *Tablo 6*'da verilmiştir.

Tablo 6. Tef ve İtalyan çimi çeşitlerin yeşil ot verimine ilişkin ortalama değerler (kg da^{-1}) ve AÖF grupları

Table 6. Aerage values and LSD groups of fresh forage yield (kg da^{-1}) of teffgrass and Italian ryegrass cultivars

Çeşit	Ekim Zamanı			Ortalama
	1 Mayıs	1 Haziran	1 Temmuz	
Tef Çeşit1 (TÇ1)	5888.3 b	7380.0 a	5152.2 bcd	6140.2 A
Tef Çeşit2 (TÇ2)	5732.5 bc	7555.8 a	5905.8 b	6398.1 A
İtalyan Çimi Çeşit1 (İÇÇ1)	4279.5 de	3470.0 e	739.2 f	2829.6 B
İtalyan Çimi Çeşit2 (İÇÇ2)	4508.2 cde	4604.2 bcde	980.8 f	3364.4 B
Ortalama	**5102.1 A**	**5752.5 A**	**3194.5 B**	**4683.0**

Ekim zamanları ortalamalarına göre en yüksek yeşil ot verimi 5752 kg da^{-1} ile 1 Haziran ekiminden elde edilmiş ve 1 Mayıs ekimi (5102.1 kg da^{-1}) ile aynı önemlilik grubunda yer almıştır (*Tablo 6*). En düşük ise 3194.5 kg da^{-1} ile 1 Temmuz ekiminden elde edilmiştir. Çeşit ortalamaları arasında en yüksek yeşil ot verimi 6398.1 kg da^{-1} ile TÇ2'den elde edilmiş ve TÇ1 (6140.2 kg da^{-1}) ile aynı önemlilik grubunda yer almıştır. En düşük yeşil ot verimi ise 2829.6 kg da^{-1} İÇÇ1'den elde edilmiş ve İÇÇ2 (3364.4 kg da^{-1}) ile arasındaki fark önemsiz çıkmıştır. Ekim zamanı x çeşit interaksiyonunda yeşil ot verimi 739.2 kg da^{-1} (1 Temmuz x İÇÇ1) – 7555.8 kg da^{-1} (1 Haziran x TÇ2) arasında değişmiştir. Çalışmada tercih ettiğimiz ekim zamanları yazlık bitkilere göre seçilmiştir. Bu nedenle yazlık bir tür olan tefin verimleri daha yüksek çıkmıştır. Çeşitlerin üç biçim ortalamasına baktığımızda Tef çeşitleri yüksek verimler elde edilirken (6140.2 kg da^{-1} (TÇ1) ve 6398.1 kg da^{-1} (TÇ2)) iken İtalyan çimi çeşitlerinden düşük verimler (2829.6 kg da^{-1} (İÇÇ1) ve 3364.4 kg da^{-1} (İÇÇ2) elde edilmiştir. Ekim zamanı x çeşit interaksiyonuna baktığımızda serin iklim bitkisi olan İtalyan çimi ekimi geciktikçe veriminde düşüşler olmuştur. Özellikle son ekim tarihi olan 1 Temmuz'da ekilen İtalyan çimi verimleri 739.2 kg da^{-1} (İÇÇ1) ve 980.8 kg da^{-1} (İÇÇ2) kadar düşmüştür. Tef bitkisinde ise farklı bir durum görülmüştür. En yüksek verimler 1 Haziran tarihinde yapılan ekimlerden 7380.0 kg da^{-1} (TÇ1) ve 7555.8 kg da^{-1} (TÇ2) alınmıştır. Genel beklenti vejetasyon süresi arttıkça yeşil ot veriminin artması şeklindedir. Ancak yürütülen bu çalışmada ekim zamanları arasında iki aylık bir süre olmasına rağmen Tef çeşitlerinin 1 Mayıs ve 1 Temmuz verimleri birbirine yakın çıkmıştır. Bu sonuçlara göre Tef çeşitleri optimum iklim koşullarında kısa vejetasyon sürelerinde bile tatmin edici verim vermektedir. Serin iklim bitkisi olan ve çalışmada kullanılan İtalyan çimi çeşitleri için ise yazlık ekimlerinin uygun olmadığını söyleyebiliriz.

Tef bitkisinde yeşil ot verimini Üke (2016) biçim zamanlarına göre 576.9 – 1061.8 kg da^{-1}, Tanık (2020) farklı sıra aralıklarına göre 2104.8 – 2766.5 kg da^{-1} ve Kaplan ve ark. (2016) farklı hasat dönemlerine göre 576.9 – 1061.8 kg da^{-1} arasında belirlemiştir. Araştırma sonuçlarından elde ettiğimiz yeşil ot verimi araştırmacıların sonuçlarından oldukça yüksek çıkmıştır. İtalyan çiminde yeşil ot verimi, Aktar ve ark. (2021) 1975.06 – 2764.75 kg da^{-1}, Dinç (1995) 2710 – 2010 kg da^{-1}, Akgül (2001) 1162. 72 kg da^{-1}, İnce (2000) 1388.7 – 2509.2 kg da^{-1}, Özdemir (2017) 2071.0 – 7368.7 kg da^{-1} ve Kamacı (2022) 3046.7 – 5210.0 kg da^{-1} arasında belirlemişlerdir. Araştırma sonuçlarımız diğer araştırmacıların sonuçlarının bazıları ile benzer iken bazılarından düşük çıkmıştır. Çalışmamızda yazlık ekim tarihlerine göre İtalyan çimini ekmemiz verim düşüklüğünde önemli bir faktör olmuştur.

3.4. Kuru ot verimi

Araştırmada ekim zamanlarının ve çeşitlerin kuru ot verimine etkisi istatistiki olarak $p<0.01$ seviyesinde önemli iken ekim zamanı x çeşit interaksiyonun etkisi $p<0.05$ seviyesinde önemli bulunmuştur. Ortalamalar arasındaki farkların önem düzeyini belirlemek için AÖF testi yapılmış, kuru ot verimine ilişkin ortalama değerler ve AÖF grupları *Tablo 7*'de verilmiştir.

Ekim zamanları ortalamalarına göre en yüksek kuru ot verimi 1529.6 kg da^{-1} ile 1 Haziran ekiminden elde edilmiş ve 1 Mayıs ekimi (1451.7 kg da^{-1}) ile arasındaki aynı önemlilik grubunda yer almıştır (*Tablo 7*). En düşük ise 1007.3 kg da^{-1} ile 1 Temmuz ekiminden elde edilmiştir. Çeşit ortalamaları arasında en yüksek kuru ot verimi 2129.1 kg da^{-1} ile TÇ2'den elde edilmiş ve TÇ1 (1934.2 kg da^{-1}) ile aynı önemlilik grubunda yer almıştır. En düşük kuru ot verimi ise 536.8 kg da^{-1} İÇÇ1'den elde edilmiş ve İÇÇ2 (718.1 kg da^{-1}) ile arasındaki fark önemsiz çıkmıştır. Ekim zamanı x çeşit interaksiyonunda kuru ot verimi 243.3 kg da^{-1} (1 Temmuz x İÇÇ1) – 2390.7 kg da^{-1} (1 Haziran x TÇ1) arasında değişmiştir.

Tablo 7. Tef ve İtalyan çimi çeşitlerin kuru ot verimine ilişkin ortalama değerler (kg da^{-1}) ve AÖF grupları

Table 7. Aerage values and LSD groups of hay yield (kg da^{-1}) of teffgrass and Italian ryegrass cultivars

Çeşit	Ekim Zamanı			Ortalama
	1 Mayıs	1 Haziran	1 Temmuz	
Tef Çeşit1 (TÇ1)	1953.3 c	2390.7 a	1458.6 d	1934.2 A
Tef Çeşit2 (TÇ2)	2007.6 bc	2336.5 ab	2043.1 abc	2129.1 A
İtalyan Çimi Çeşit1 (İÇÇ1)	805.0 ef	562.1 fg	243.3 g	536.8 B
İtalyan Çimi Çeşit2 (İÇÇ2)	1040.9 e	829.2 ef	284.2 g	718.1 B
Ortalama	**1451.7 A**	**1529.6 A**	**1007.3 B**	**1329.5**

Çeşit ortalamalarına baktığımızda Tef çeşitlerinin kuru ot verim ortalaması İtalyan çimi çeşitlerinin verim ortalamasından yüksek çıkmıştır. Ekim zamanı x çeşit interaksiyonuna baktığımızda İtalyan çimi çeşitleri ekim zamanı ilerledikçe verimlerinde önemli düşüşler görülmüştür. Ekim tarihi geciktikçe bitkilerin gelişimi yaz dönemine gelmekte ve serin iklim bitkisi olan İtalyan çimi olumsuz etkilenmektedir. Tef çeşitlerinde ise en yüksek kuru ot verimi 1 Haziran ekiminden elde edilmiştir. Tef Çeşit1 en düşük kuru ot verimini 1 Temmuz tarihinde yapılan ekimde verirken Tef Çeşit2 1 Mayıs tarihinde ekiminde vermiş ve geç ekimde (1 Temmuz) bile oldukça verimli olmuştur.

Üke (2016) tef bitkisinde kuru ot verimini 198.5 – 637.0 kg da^{-1} arasında ve hasat zamanının ilerlemesiyle kuru ot veriminde artış bulmuştur. Tanık ve Kökten (2021) kuru ot verimini755.1 – 974.7 kg da^{-1} arasında belirlemiş ve sıra aralığının kuru ot verimine etkisini önemli tespit etmiştir. Kaplan ve ark. (2016) farklı hasat dönemlerine göre 198.5 – 637.0 kg da^{-1} arasında belirlemişlerdir. Kuru ot verimi yetiştirilen bölgenin iklim ve toprak özellikleri, tane ya da ot için ıslah edilen çeşidin verim potansiyeli, uygulanan ekim zamanı, gübreleme, biçim sayısı, sulama gibi tarımsal uygulamaların etkisi ortaya çıkmaktadır. Dolayısı ile bu faktörlere bağlı olarak çalışmalar arasında verim farkları oluşmuştur.

İtalyan çiminde kuru ot verimini Aktar ve ark. (2021) 484 – 746 kg da^{-1}, Dinç (1995) 584.43 – 415.13 kg da^{-1}, İnce (2000) 314 – 567.3 kg da^{-1}, Kamacı (2022) 800.3 -1339.0 kg da^{-1} arasında bulmuşlardır. Yazlık ekim yaptığımız çalışmamızdan elde ettiğimiz sonuçlar araştırmacıların çoğunun sonuçlarından daha düşük çıkmıştır. Düşük olmasında nedeni olarak serin iklim bitkisi olan İtalyan çiminde kullandığımız çeşitlerin yazlık ekimden olumsuz etkilenmesi gösterilebilir.

3.5. Kuru madde oranı

Araştırmada sonuçları incelendiğinde ekim zamanlarının, çeşitlerin ve ekim zamanı x çeşit interaksiyonun kuru madde (KM) oranına etkisi istatistiki olarak $p<0.01$ seviyesinde önemli bulunmuştur. Ortalamalar arasındaki farkların önem düzeyini belirlemek için AÖF testi yapılmış, kuru madde oranına ilişkin ortalama değerler ve AÖF grupları *Tablo 8*'de verilmiştir.

Ekim zamanları ortalamalarına göre en yüksek kuru madde oranı %28.65 ile 1 Temmuz'da hesaplanmış 1 Mayıs (%25.21) ve 1 Haziran (%22.21) ekimleri takip etmiştir. Çeşit ortalamaları arasında en yüksek kuru madde oranı %30.73 ile TÇ2 de belirlemiş ve TÇ1 (%28.48) ile aynı önemlilik grubunda yer almıştır. En düşük kuru madde oranı ise %20.68 ile İÇÇ1 de hesaplanmış ve İÇÇ2 (%21.52) ile arasındaki fark önemsiz çıkmıştır. Çeşit ortalamalarına baktığımızda genel olarak Tef Çeşitlerinin kuru madde oranları İtalyan çimi çeşitlerinin kuru madde oranlarının oldukça üzerinde çıkmıştır. Ekim zamanı x çeşit interaksiyonunda kuru madde oranı %14.73 – %32.14 (1 Haziran x İÇÇ – 1 Mayıs x TÇ2) arasında değişmiştir.

Ekim zamanları ortalamalarına göre en yüksek kuru madde oranı %28.65 ile 1 Temmuz'da hesaplanmış 1 Mayıs (%25.21) ve 1 Haziran (%22.21) ekimleri takip etmiştir. Çeşit ortalamaları arasında en yüksek kuru madde oranı %30.73 ile TÇ2 de belirlemiş ve TÇ1 (%28.48) ile aynı önemlilik grubunda yer almıştır. En düşük kuru madde oranı ise %20.68 ile İÇÇ1 de hesaplanmış ve İÇÇ2 (%21.52) ile arasındaki fark önemsiz çıkmıştır. Çeşit ortalamalarına baktığımızda genel olarak Tef çeşitlerinin kuru madde oranları İtalyan çimi çeşitlerinin kuru madde oranlarının oldukça üzerinde çıkmıştır. Ekim zamanı x çeşit interaksiyonunda kuru madde oranı %14.73 – %32.14 (1 Haziran x İÇÇ1 – 1 Mayıs x TÇ2) arasında değişmiştir.

Tablo 8. Tef ve İtalyan çimi çeşitlerin KM oranına ilişkin ortalama değerler (%) ve AÖF grupları

Table 8. Aerage values and LSD groups of dry matter content (%) of teffgrass and Italian ryegrass cultivars

Çeşit	Ekim Zamanı			Ortalama
	1 Mayıs	1 Haziran	1 Temmuz	
Tef Çeşit1 (TÇ1)	29.93 ab	29.53 ab	25.98 bc	28.48 A
Tef Çeşit2 (TÇ2)	32.14 a	28.31 ab	31.74 ab	30.73 A
İtalyan Çimi Çeşit1 (İÇÇ1)	17.19 de	14.73 e	30.13 ab	20.68 B
İtalyan Çimi Çeşit2 (İÇÇ2)	21.57 cd	16.25 de	26.73 abc	21.52 B
Ortalama	**25.21 B**	**22.21 C**	**28.65 A**	**25.35**

Tef bitkisinde kuru madde oranını Gürün ve Geren (2019) %21.9 – 23.0 arasında be Geren ve ark. (2019) 21.9 – 23.1 arasında belirlemişlerdir. Bu değerler çalışmamızda bulduğumuz değerlerden daha düşüktür. İtalyan çiminde kuru madde oranını Kamacı (2022) %21.9 – 26.4 arasında ve Yalçın (2019) %35.6 – 43.0 arasında belirlemişlerdir. Araştırmamızdan elde ettiğimiz kuru madde oranları bu değerlerden daha düşük çıkmıştır.

3.6. Kuru madde verimi

Araştırmada kuru madde verimine ekim zamanlarının ve çeşitlerin etkisi istatistiki olarak $p<0.01$ seviyesinde önemli iken, ekim zamanı x çeşit interaksiyonunun etkisi $p<0.05$ seviyesinde önemli bulunmuştur. Ortalamalar arasındaki farkların önem düzeyini belirlemek için AÖF testi yapılmış, kuru madde verimine ilişkin ortalama değerler ve AÖF grupları *Tablo 9*'da verilmiştir.

Tablo 9. Tef ve İtalyan çimi çeşitlerin KM verimine ilişkin ortalama değerler (kg da^{-1}) ve AÖF grupları

Table 9. Aerage values and LSD groups of dry matter yield (kg da^{-1}) of teffgrass and Italian ryegrass cultivars

Çeşit	Ekim Zamanı			Ortalama
	1 Mayıs	1 Haziran	1 Temmuz	
Tef Çeşit1 (TÇ1)	1782.6 c	2176.2 a	1335.0 d	1764.6 A
Tef Çeşit2 (TÇ2)	1833.2 bc	2137.8 ab	1864.8 abc	1945.2 A
İtalyan Çimi Çeşit1 (İÇÇ1)	733.2 ef	510.8 fg	221.4 g	488.5 B
İtalyan Çimi Çeşit2 (İÇÇ2)	952.6 e	755.7 ef	257.5 g	655.3 B
Ortalama	**1325.4 A**	**1395.1 A**	**919.7 B**	**1213.4**

Ekim zamanları ortalamalarına göre en yüksek kuru madde verimi 1395.1 kg da^{-1} ile 1 Haziran ekiminden elde edilmiş ve 1 Mayıs ekimi (1325.4 kg da^{-1}) ile aynı önemlilik grubunda yer almıştır (*Tablo 9*). En düşük ise 919.7 kg da^{-1} ile 1 Temmuz ekiminden elde edilmiştir. Çeşit ortalamaları arasında en yüksek kuru madde verimi 1945.2 kg da^{-1} ile TÇ2'den elde edilmiş ve TÇ1 (1764.6 kg da^{-1}) ile aynı önemlilik grubunda yer almıştır. En düşük kuru madde verimi ise 488.5 kg da^{-1} İÇÇ1'den elde edilmiş ve İÇÇ2 (655.3 kg da^{-1}) ile arasındaki fark önemsiz çıkmıştır. Ekim zamanı x çeşit interaksiyonunda kuru madde verimi 221.4 – 2176.2 kg da^{-1} (1 Temmuz x İÇÇ1 – 1 Haziran x TÇ1) arasında değişmiştir. Ekim zamanı x çeşit interaksiyonuna baktığımızda serin iklim bitkisi olan İtalyan çimi ekimi geciktikçe veriminde düşüşler olmuştur. Özellikle son ekim tarihi olan 1 Temmuz'da ekilen İtalyan çimi verimleri 221.4 kg da^{-1} (İÇÇ1) ve 257.5 kg da^{-1} (İÇÇ2) kadar düşmüştür. Tef bitkisinde ise farklı bir durum görülmüştür. En yüksek verimler 1 Haziran tarihinde yapılan ekimlerden 2176.2 kg da^{-1} (TÇ1) ve 2137.8 kg da^{-1} (TÇ2) alınmıştır. Genel beklenti vejetasyon süresi uzadıkça yeşil ot veriminin artması şeklindedir. Ancak yürütülen bu çalışmada ekim zamanları arasında iki aylık bir süre olmasına rağmen TÇ2'de 1Temmuz ekimlerinin verimi 1 Mayıs ekimindeki veriminden yüksek çıkmıştır. Yine TÇ1'de 1Temmuz ekiminde oldukça iyi bir verim alınmıştır. Orta Anadolu koşullarında 1 Temmuz'da ikinci ürün ekim tarihinde Tef çeşitleri oldukça iyi kuru madde verimi vererek ikinci ürün olarak ekilebilme potansiyelini ortaya koymuştur. Serin iklim bitkisi olan ve çalışmada kullanılan İtalyan çimi çeşitleri için ise yazlık ekimlerinin uygun olmadığını söyleyebiliriz.

Tef bitkisinde kuru madde verimini Gürün ve Geren (2019) 660 – 812 kg da^{-1} arasında ve Geren ve ark. (2019) 635 – 816 kg da^{-1} belirlemişlerdir. Çalışmamızda ise tef çeşitlerinin ortalama kuru madde verimleri (1764.6 – 1945.2 kg da^{-1}) araştırmacıların sonuçlarından oldukça yüksek çıkmıştır. Bunda kullanılan çeşitleri, çalışmaların

yürütüldüğü bölgelerin ve uygulamaların farklılığı etkili olmuştur. İtalyan çiminde kuru madde verimimiz Kamacı (2022)'nın sonuçlarından (160.7 – 375.9 kg da^{-1}) daha yüksek iken Özdemir (2017) 'in sonuçlarından (518.9 – 1773.9 kg da^{-1}) ve Çetin (2017)'in sonuçlarından (781.9 – 1222.6 kg da^{-1}) daha düşük çıkmıştır. Bunun nedeni çalışma konularındaki farklılıklardan kaynaklanmış olabilir.

3.7. Ham Protein Oranı

Araştırmada ekim zamanlarının, çeşitlerin ve ekim zamanı x çeşit interaksiyonun ham protein (HP) oranına etkisi istatistiki olarak p<0.01 seviyesinde önemli bulunmuştur. Ortalamalar arasındaki farkların önem düzeyini belirlemek için AÖF testi yapılmış, ham protein oranına ilişkin ortalama değerler ve AÖF grupları *Tablo 10*'da verilmiştir.

Tablo 10. Tef ve İtalyan çimi çeşitlerin HP oranına ilişkin ortalama değerler (%) ve AÖF grupları

Table 10. Aerage values and LSD groups of crude protein rate (%) of teffgrass and Italian ryegrass cultivars

Çeşit	Ekim Zamanı			Ortalama
	1 Mayıs	1 Haziran	1 Temmuz	
Tef Çeşit1 (TÇ1)	6.12 g	6.88 f	8.55 d	7.18 B
Tef Çeşit2 (TÇ2)	6.22 g	6.43 fg	7.92 e	6.86 C
İtalyan Çimi Çeşit1 (İÇÇ1)	11.19 a	11.04 a	9.45 c	10.56 A
İtalyan Çimi Çeşit2 (İÇÇ2)	10.75 a	10.95 a	10.15 b	10.62 A
Ortalama	**8.57 B**	**8.82 AB**	**9.02 A**	**8.80**

Ekim zamanları ortalamalarına göre en yüksek kuru madde oranı %9.02 ile 1 Temmuz'da belirlenmiş bunu 1 Haziran (%8.82) ve 1 Mayıs (%8.57) ekimleri takip etmiştir. Ekim tarihleri yaza doğru kaydıkça ham protein oranlarında artışlar görülmüştür. Çeşit ortalamaları arasında en yüksek ham protein oranı %10.62 ile İÇÇ2'de belirlemiş ve İÇÇ1 (%28.48) ile aynı önemlilik grubunda yer almıştır. En düşük ham protein oranı ise %6.86 ile TÇ2 de hesaplanmış ve TÇ1 (%7.18) ile arasındaki fark önemsiz çıkmıştır. Çeşit ortalamalarına baktığımızda genel olarak İtalyan çimi çeşitlerinin ham protein oranları Tef çeşitlerinin kuru madde oranlarının üzerinde çıkmıştır. Ekim zamanı x çeşit interaksiyonunda ham protein oranı %6.12 – %11.19 (1 Mayıs x TÇ1 – 1 Mayıs x İÇÇ1) arasında değişmiştir. İtalyan çimi çeşitlerinin ham protein oranı ekim zamanı geciktikçe çok fazla değişmemiştir. Ancak Tef çeşitlerin ekim zamanı geciktikçe ham protein oranlarında anlamlı artışlar olmuştur. Tef çeşitlerinde en yüksek ham protein oranları 1 Temmuz ekimlerinden elde edilmiştir.

Tef bitkisinde am protein oranını araştırmacılardan Sang-Hoon ve ark. (2015) 8.21 – 9.52, Davison ve ark. (2011) %8.1-15.0, Üke (2016) %6.57-13.35, Tanık (2020) %15.64-18.82, Kakabouki ve ark. (2020) %14.2-18.9, Gürün ve Geren (2019) %11.9-13.0, Geren ve ark. (2019) %11.9 – 13.0 ve Kaplan ve ark. (2016) 6.57 – 13.35 arasında belirlemişlerdir. İtalyan çiminde ham protein oranını Aktar (2019) 10.03 – 12.13, Özdemir (2017) %12.65 – 18.34, Acar (2020) %11.21 – 15.47, Kamacı (2022) %8.9 – 15.5, Lale (2020) %14.63 – 21.13 ve Akgül (2001) %14.38 – 20.84 arasında bulmuşlardır. Çalışma sonuçlarımız ile bazı araştırmacıların sonuçları benzer, bazılarının sonuçlarından daha düşük veya yüksek olmuştur. Bunun nedeni ham protein oranına etki eden çeşit, çevre koşulları, sulama, gübreleme, ekim sıklığı, gelişme dönemi gibi tarımsal uygulamalardaki farklılıklar gösterilebilir.

3.8. Ham protein verimi

Araştırmada ekim zamanlarının, çeşitlerin ve ekim zamanı x çeşit interaksiyonun ham protein verimine etkisi istatistiki olarak p<0.01 seviyesinde önemli bulunmuştur. Ortalamalar arasındaki farkların önem düzeyini belirlemek için AÖF testi yapılmış, ham protein verimine ilişkin ortalama değerler ve AÖF grupları *Tablo 11*'de verilmiştir.

Ekim zamanları ortalamalarına göre en yüksek ham protein verimi 106.3 kg da^{-1} ile 1 Haziran ekiminden elde edilmiş ve 1 Mayıs ekimi (101.6 kg da^{-1}) ile aynı önemlilik grubunda yer almıştır (*Tablo 11*). En düşük ise 77.2 kg da^{-1} ile 1 Temmuz ekiminden elde edilmiştir. Çeşit ortalamaları arasında en yüksek ham protein verimi 132.9 kg da^{-1}ile TÇ2'den elde edilmiş ve TÇ1 (124.0 kg da^{-1}) ile aynı önemlilik grubunda yer almıştır. En düşük ham protein verimi ise 53.0 kg da^{-1} İÇÇ1'den elde edilmiş ve İÇÇ2 (70.2 kg da^{-1}) ile arasındaki fark önemsiz çıkmıştır.

Ekim zamanı x çeşit interaksiyonunda ham protein verimi 20.9 – 149.7 kg da^{-1} (1 Temmuz x İÇÇ1 – 1 Haziran x TÇ1) arasında değişmiştir. Yazlık ekim koşullarında tropik kökenli tef bitkisi serin iklim bitkisi olan İtalyan çiminden daha fazla yeşil ot, kuru madde oranı, kuru madde verimi vermiştir. Tef çeşitlerinin ham protein oranı İtalyan çimi çeşitlerinden daha düşük olsa da kuru madde veriminin yüksekliği nedeni ile toplam ham protein verimi daha fazla çıkmıştır. Özellikle 1 Temmuz ekim tarihinde Tef çeşitlerinin ham protein verimleri İtalyan çimi çeşitlerinin ham protein verimlerinden çok fazla olmuştur. Bu sonuçlara göre Tef çeşitleri optimum iklim koşullarında kısa vejetasyon sürelerinde bile tatmin edici ham protein verimi vermektedir. Serin iklim bitkisi olan ve çalışmada kullanılan İtalyan çimi çeşitleri için ise yazlık ekimlerinin uygun olmadığını söyleyebiliriz.

Tablo 11. Tef ve İtalyan çimi çeşitlerin HP verimine ilişkin ortalama değerler (kg da^{-1}) ve AÖF grupları

Table 11. Aerage values and LSD groups of CP yield (kg da^{-1}) of teffgrass and Italian ryegrass cultivars

	Ekim Zamanı			Ortalama
Çeşit	**1 Mayıs**	**1 Haziran**	**1 Temmuz**	
Tef Çeşit1 (TÇ1)	108.3 bcd	149.7 a	114.1 bc	124.0 A
Tef Çeşit2 (TÇ2)	113.8 bc	137.3 ab	147.5 a	132.9 A
İtalyan Çimi Çeşit1 (İÇÇ1)	82.0 de	56.1 ef	20.9 g	53.0 B
İtalyan Çimi Çeşit2 (İÇÇ2)	102.3 cd	82.1 de	26.1 fg	70.2 B
Ortalama	**101.6 A**	**106.3 A**	**77.2 B**	**95.0**

Tef bitkisinde ham protein verimini Tanık (2020) 118.2 – 180.8 kg da^{-1} arasında belirlemiştir. Bu sonuçlar araştırma sonuçlarımız ile yakın bulunmuştur. İtalyan çiminde ham protein verimini araştırmacılardan Akgül (2001) 30.83 – 79.89 kg da^{-1}, Çetin (2017) 91.6 – 172.5 kg da^{-1}, Pak Örün (2019) 57.6 – 121.4 kg da^{-1}, Çolak (2015) 36.12 – 68.18 kg da^{-1}, Özdemir (2017) 49.3 – 266.9 kg da^{-1} ve Yalçın (2019) 66.25 – 80.66 kg da^{-1} arasında değiştiğini tespit etmişlerdir. Çalışma sonuçlarımız araştırmacıların bazılarının sonuçları ile benzer iken, bazılarının sonuçlarından daha düşük veya yüksek olmuştur. Bunun nedenleri arasında bitki boyuna etki eden çeşit, çevre koşulları, sulama, gübreleme, ekim sıklığı gibi tarımsal uygulamalardaki farklılıklar olabilir.

4. Sonuçlar ve Öneriler

Sıcak koşullarda hızlı bir şekilde büyüyen tef ekimden kısa bir süre sonra biçim olgunluğuna gelmekte, iklim koşullarına göre birden çok biçilebilmektedir. Tropik kökenli tef bitkisine son yıllarda ilgi artmış ve Türkiye'de de yavaş yavaş ekilmeye başlanmıştır. Konya bölgesinde bu bitkinin verim potansiyelinin ve tarımsal uygulamalarının geliştirilmesine ihtiyaç vardır. Bu nedenle Konya bölgesinde Tef bitkisinin verim potansiyelini görmek ve ekim zamanlarına göre verim ve kalitesini belirlemek amacıyla bu çalışma yapılmıştır. Bölge tarımında tef bitkisinin yer alabilmesi için aynı amaç için kullanılan mevcut tarımı yapılan bitkilere göre artılarının olmasına bağlıdır. Çalışmada mevcutta ekimi yapılan İtalyan çimi ile bölgemiz için yeni bir bitki olan tef bitkisinin farklı zamanlarda ekimlerine göre verim ve kaliteleri kıyaslanmış, özellikle sıcak yaz döneminde gelişimi yavaşlayan İtalyan çimi yerine tef bitkisinin kullanılabilme potansiyeli ortaya konmuştur. Çalışmadan elde edilen sonuçlar aşağıda verilmiştir.

İncelenen tüm özellikler üzerine ekim zamanı, çeşitler ve ekim zamanı x çeşit interaksiyonu önemli olmuştur. Tef bitkisi ile İtalyan çiminin bitki boyu genel olarak birbirine yakınken, İtalyan çiminin sap kalınlığı tef bitkilerinden daha fazla olmuştur.

Çalışmada ekim tarihleri yazlık ekime göre seçilmiştir. Bu nedenle yazlık bir tür olan tefin verimleri daha yüksek çıkmıştır. Çeşitlerin üç biçim ortalamasına baktığımızda çalışmada kullanılan iki Tef çeşidinin ortalama verimi 6269.2 kg da^{-1} ((6140.2 + 6398.1) / 2) iken İtalyan çimi çeşitlerinin ortalama verimi 3097.0 kg da^{-1} ((2829.6 + 3364.4) / 2) olmuştur. Tef çeşitleri İtalyan çimi çeşitlerinin yeşil ot veriminin yaklaşık iki katı verim vermiştir. Özellikle 1 Temmuz'da yapılan ekimlerde bu fark 6-7 kata kadar çıkmaktadır. Sıcak iklim bitkisi olan tef doğal olarak yaz ekimlerinde açık bir şekilde İtalyan çiminden daha fazla yeşil ot verimi vermektedir. Genel olarak vejetasyon süresi arttıkça yeşil ot veriminin artması beklenmektedir. Ancak yürütülen bu çalışmada ekim zamanları arasında iki aylık bir süre olmasına rağmen Tef çeşitlerinin 1 Mayıs ve 1 Temmuz verimleri birbirine yakın çıkmıştır. Bu sonuçlara göre; Tef çeşitleri optimum iklim koşullarında kısa vejetasyon sürelerinde bile tatmin edici yeşil ot vermektedir. Serin iklim bitkisi olan ve çalışmada kullanılan İtalyan çimi çeşitleri için ise yazlık ekimlerinin uygun olmadığını söyleyebiliriz.

Kuru ot verimi açısından baktığımızda Tef bitkisi İtalyan çiminden daha verimli olmuştur. Çeşitlerin üç biçim

ortalamasına baktığımızda çalışmada kullanılan iki Tef çeşidinin ortalama kuru ot verimi 2031.7 kg da^{-1} ((1934.2 + 2129.1) / 2) iken İtalyan çimi çeşitlerinin ortalama kuru ot verimi 627.5 kg da^{-1} ((536.8 + 718.1) / 2) olmuştur. Tef çeşitlerinin ortalama kuru ot verimi İtalyan çimi çeşitlerinin kuru ot veriminin üç katından biraz fazla olmuştur.

Kuru madde oranları tef çeşitlerinde İtalyan çimi çeşitlerinden daha yüksek çıkmıştır. Tef çeşitlerin deneme koşullarında hem yeşil ot veriminin yüksek olması hem de kuru madde oranının yüksek olması çarpan etkisi ile kuru madde veriminin de İtalyan çiminden yüksek olmasına neden olmuştur. Çeşitlerin üç biçim ortalamasına baktığımızda çalışmada kullanılan iki Tef çeşidinin ortalama kuru madde verimi 1854.9 kg da^{-1} ((1764.6 + 1945.2) / 2) iken İtalyan çimi çeşitlerinin ortalama kuru ot verimi 571.9 kg da^{-1} (488.5 + 655.3) / 2) olmuştur. Tef çeşitlerinin ortalama kuru madde verimi İtalyan çimi çeşitlerinin kuru ot veriminin üç katından biraz fazla olmuştur.

Ham protein analiz sonuçlarına göre İtalyan çimi çeşitlerinin ham protein oranları (%10.56, %10.62) tef çeşitlerinin ham protein oranlarından (%7.18, %6.86) daha yüksek çıkmıştır. Genel anlamda ham protein oranı yönünden İtalyan çimi çeşitleri Tef çeşitlerine tercih edilebilir. Ancak ham protein verimi açısından baktığımızda Tef çeşitlerinin ham protein oranı düşük olsa bile kuru madde verimlerinin yüksek olmasına bağlı olarak dekara ham protein verimleri İtalyan çimine göre oldukça yüksek çıkmıştır.

Elde ettiğimiz tüm sonuçları birlikte değerlendirdiğimizde;

Orta Anadolu koşullarında yazlık ekim tarihlerinde Tef çeşitleri İtalyan çimi çeşitlerinden daha verimli olmaktadır.

Tef bitkisi Orta Anadolu koşullarında ekimden 55-65 gün içerisinde biçim olgunluğuna gelmektedir. Tef bitkisi Orta Anadolu koşullarında ikinci ürün olarak 1 Temmuz'da ekildiğinde bile iki kez biçilebilmekte ve iyi bir verim verebilmektedir.

Çalışmada kullanılan İtalyan çimi çeşitleri için 1 Mayıs ve sonraki tarihlerde ekimlerinin düşük verime neden olmaktadır. Serin iklim bitkisi olan İtalyan çiminin çeşitler dikkate alınarak daha erken ekilmesi uygun olacaktır.

Ülkemizde çok fazla tef çeşidi bulunmamaktadır. Daha fazla çeşitle benzer çalışmaların yapılması uygun olacaktır. Ayrıca tef yetiştiriciliğinin geliştirilmesi için sulama, gübreleme, ekim sıklığı gibi tarımsal uygulamaların denenmesi gerekmektedir.

Teşekkür

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Estimation of Monthly, Seasonal and Annual Total Solar Radiation on the Tilted Surface at Optimum Tilt Angles in Two Provinces, Turkiye

Türkiye'de İki İlde Optimum Eğim Açılarında Eğimli Yüzeyde Aylık, Mevsimsel, Yıllık Toplam Güneş Işınımının Tahmini

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Abstract

In solar energy systems that use solar panels, it's important to know the best tilt angle to optimize solar energy production. Monthly, seasonal, and annual optimum tilt angles were determined in this study using meteorological insolation data from many years in the provinces of Tekirdag and Konya, which are located in different regions of Turkey. At optimum tilt angles, monthly, seasonal, and annual total radiation on the tilted surface were 1516.7 kWh m^{-2} $year^{-1}$, 1504.1 kWh m^{-2} $year^{-1}$ and 1448.1 kWh m^{-2} $year^{-1}$ in Tekirdag, respectively. In Konya, these values were 1851.4 kWh m^{-2} $year^{-1}$, 1833.51 kWh m^{-2} $year^{-1}$ and kWh m^{-2} $year^{-1}$, respectively. In the seasonal and annual optimum tilt angles, there was an approximately 1% and 5% loss in the total radiation values on the tilted surface, respectively, according to the monthly optimum tilt angle. In addition, the coefficients of the relationship between the monthly mean daily radiation on the tilted surface and the tilt angles were determined for each month using the cubic regression model in both provinces. The Cubic regression model coefficients are computed for each month in the provinces of Tekirdag and Konya. All months in both provinces had R^2 (Coefficient of determination) values of 0.999 for the Cubic model. To determine whether there is a difference between the total amounts of radiation reaching the tilted surface for each month at the best tilt angles obtained by the two methods, the t-test was used. The monthly average daily radiation values on the tilted surface obtained by the two methods at the best tilt angles in both provinces have not been found to differ statistically ($p>0.05$; $t=0.001$).

Keywords: Solar radiation, Extraterrestrial radiation, Tilted surface, Optimum tilt angle, Cubic regression model

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Öz

Güneş panelleri kullanılan güneş enerjisi sistemlerinde, güneş enerjisi üretimini optimize etmek için panellerin konumlandırılacağı yerde monte edilirken kullanılacak, en iyi eğim açısını bilmek önemlidir. Bu çalışmada Türkiye'nin coğrafi olarak farklı bölgelerinde yer alan Tekirdağ ve Konya illerinde uzun yıllara ait meteorolojik güneşlenme verileri kullanılarak aylık, mevsimsel ve yıllık optimum güneş paneli eğim açıları belirlenmiştir. Tekirdağ ili için hesaplanan optimum eğim açılarında, eğimli yüzeydeki aylık, mevsimsel ve yıllık toplam güneş ışınımı sırasıyla 1516.7 m^{-2} $yıl^{-1}$, 1504.1 kWh m^{-2} $yıl^{-1}$ ve 1448.1 m^{-2} $yıl^{-1}$ olmuştur. Konya ili için yapılan hesaplamalarda ise bu değerler sırasıyla 1851.4 m^{-2} $yıl^{-1}$, 1833.51 m^{-2} $yıl^{-1}$ ve 1754.7 m^{-2} $yıl^{-1}$ olarak bulunmuştur. Mevsimsel ve yıllık optimum eğim açılarında, eğimli yüzeyde elde edilen toplam güneş ışınımı değerlerinde aylık optimum eğim açısına göre sırasıyla yaklaşık %1 ve %5 oranında kayıp olduğu görülmüştür. Ayrıca eğimli yüzeydeki aylık ortalama günlük ışınım ile panel eğim açıları arasındaki ilişkinin katsayıları her ay için kübik regresyon modeli kullanılarak belirlenmiştir. Kübik regresyon modeli katsayıları Tekirdağ ve Konya illerinde her ay için ayrı ayrı hesaplanmıştır. Kübik regresyon modeli için her iki ilde de tüm ayların R^2 (Determinasyon Katsayısı) değeri 0,999'dur. Yüksek R^2 değeri seçilen modelin bağımsız değişkeni olan panel eğim açılarındaki varyansın, bağımlı değişken olan eğimli yüzeydeki aylık ortalama günlük ışınımın sahip olduğu varyansın 99.9%' unu açıklayabildiğini göstermektedir. İki yöntemle elde edilen en iyi eğim açılarında eğimli yüzeye aylara göre ulaşan toplam güneş ışınımı miktarları arasında fark olup olmadığını belirlemek için t-testi kullanılarak karşılaştırma yapılmıştır. Her iki ilde en iyi eğim açılarında iki yöntemle elde edilen eğimli yüzeydeki aylık ortalama günlük güneş ışınımı değerleri istatistiksel olarak farklılık göstermemiştir ($p>0,05$; $t=0,001$).

Anahtar Kelimeler: Güneş Işınımı, Uzay Işınımı, Eğik Yüzey, Optimum Eğim Açısı, Kübik Regresyon Modeli

1. Introduction

Determining the optimum tilt angle of the solar panel in a region where a solar energy system will be installed is an important parameter in terms of energy efficiency (Altan et al., 2021; Diken and Kayisoglu, 2022). The technical staffs who install the system generally ignore the optimum tilt angle and determine it according to the criteria, which are not based on scientific basis. The most efficient way to benefit from solar energy in solar panels is to use solar tracking systems. In a study, it was stated that when solar tracking systems are used, there is a 43.87% more daily total energy gain than fixed systems (Abdallah, 2004). Tomson (2008) stated that seasonal energy yield increased 10–20% of collectors which are used the two-positional tracking system. However, solar tracking systems are fairly costly and are more cost-effective when utilized in solar power plants where solar energy is utilized extensively (Despotovic and Nedic, 2015). Thus, they are not advised for use in smaller solar panel installations (Mousazadeh et al., 2009). Determining the annual, seasonal or monthly optimum tilt angles in relatively small panel systems where solar tracking systems are not economical gains importance in terms of increasing the amount of energy collected on the tilted surface of collector. For this purpose, a lot of research has been done and numerous models have been used. Gong and Kulkarni (2005) stated in their research that the optimum tilt angle is close to site's latitude degree in conditions where the azimuth angle is zero, but it is lower in some cases. Using a mathematical model, the total solar radiation on the tilted PV (Photovoltaic) surface was estimated, and the optimal tilt angles for a PV panel installed in Sanliurfa, Turkey were determined. Researchers stated that the optimum tilt angle of PV panels for Sanliurfa is 14º (Kacira et al., 2004). In a study conducted in China, optimum tilt angles were determined for 30 cities by using the actual monthly global and diffuse radiation values on horizontal surface of 152 settlements (Tang and Wu, 2004). In a study investigating the performance of PV systems placed at different angles in Brisbane, Australia, it was stated that the theoretical optimal tilt angle was approximately 26º facing true North (Yan et al., 2013). Using annual optimal tilt angles as opposed to monthly optimum tilt angles resulted in projected energy losses of 5.68 percent for Aligarh and 4.91 percent for New Delhi. Based on the study, it was suggested that the inclined surface be tilted at the optimal monthly or seasonal tilt angle for optimal solar energy generation (Jamil et al., 2016). Vieira et al. (2016) in their experimental study, they stated that there is a low average energy gain in panels using solar tracking system compared to fixed panels.

There are numerous models for estimating the total radiation incident on the tilted surface with the help of global radiation incident on the horizontal surface. In most of these models, direct, diffuse and reflected radiation predictions are made (Muzathik et al., 2011). There are also many empirical models developed using available meteorological data in order to calculate total radiation on the tilted surface (Psiloglou and Kambezidis, 2007). Using the data obtained from the Turkish State Meteorological Service, Bakirci (2009) used 7 models to estimate the monthly average daily amount of global radiation in many provinces, Turkey, and compared them.

In this study, it was aimed to determine the monthly, seasonal and annual optimum tilt angles by using monthly average daily radiation data obtained from the Turkish State Meteorological Service in Tekirdağ and Konya provinces, Turkey. Tekirdag is in the Thrace region in the northwest of Turkey. Konya is in the Central Anatolian region. Intensive industrial and agricultural activities are carried out in both provinces and there is a large amount of energy consumption. In addition, the relationship between the angle of tilt and the monthly average daily total radiation on the tilted surface was also investigated for each month.

2. Materials and Methods

Latitudes, longitudes and altitudes of provinces where this research was conducted are given in *Table 1*. Tekirdag is on the west and coast of the Marmara Sea. Konya is quite far from the sea and is located in the Central Anatolian region.

Table 1. Laritudes, longitudes and altitudes of provinces

City	Latitude (º)	Longitude (º)	Altitude (m)
Tekirdag	40.98	27.52	37
Konya	37.87	32.48	1023

The daily extraterrestrial radiation on horizontal surface on northern hemisphere has been calculated by the equation given below (Eq. 1) (Duffie and Beckman, 1991; Türk Togrul and Onat, 1999);

$$H_o = \frac{24G_{sc}k}{\pi} * \left(\cos\delta\cos\phi\sin\omega_s + \frac{\pi\omega_s}{180}\sin\delta\sin\phi\right) \quad \text{(Eq.1).}$$

Where, H_o is the Daily extraterrestrial radiation on horizontal surface (kWh m^{-2} day^{-1}), G_{sc} is the solar constant (1367 W m^{-2}), k is the eccentricity correction factor and calculated the equation (Eq. 2) given below;

$$k = \left(1 + 0.033\cos\frac{360n}{365}\right) \quad \text{(Eq.2).}$$

Where, n is the number of the day of the year starting from the first of January.

Sunset hour angle is calculated by the following equation (Eq. 3) (Cooper, 1969; Yorukoglu and Celik, 2006);

$$\omega_s = \cos^{-1}(-\tan\delta\tan\phi) \quad \text{(Eq.3).}$$

Where; ω_s is the sunset hour angle (º), δ is the declination angle (º) and ϕ is the latitude of site (º).

The declination angle is calculated with the following equation (Eq. 4) in the northern hemisphere according to certain days of the year (Cooper, 1969; Ertekin and Yaldiz, 1999);

$$\delta = 23.45 * \sin\left(360\frac{(284-n)}{365}\right) \quad \text{(Eq.4).}$$

The calculated average declination and hour angles for days specified in *Table* 2 have been used to calculate the monthly average daily radiation on the tilted surfaces (Mehleri et al., 2010; Bakirci, 2012).

Table 2. Recommended average declination and hour angles for each month in the northern hemisphere

Month	Day	n	δ (°)	ω_s (°)
January	17	17	-20.92	70.6
February	16	47	-13.00	78.4
March	16	75	-2.40	87.9
April	15	105	9.40	98.3
May	15	135	18.80	107.2
June	11	162	23.10	111.8
July	17	198	21.20	109.7
August	16	228	13.50	102.0
September	15	258	2.20	91.9
October	15	288	-9.60	81.5
November	14	318	-18.90	72.7
December	10	344	-23.00	68.3

Many models have been developed to determine the amount of diffuse radiation using the monthly daily global solar radiation. In this study, the model developed by Erbs et al. (1982) was used. In this model, after calculating the monthly daily average clearness index using monthly average values, cubic relations between diffuse radiation and global radiation reaching the earth are developed. The average clearness index has been calculated for each month as below (Eq. 5) (Duffie and Beckman, 1991);

$$\bar{K}_T = \frac{\bar{H}_g}{\bar{H}_0} \quad \text{(Eq.5).}$$

Where; $\bar{H}_g$ is the montly daily average global radiation on horizontal surface (kWh/m^2.day), $\bar{H}_0$ is the monthly daily average extraterrestrial radiation (kWh m^{-2} day^{-1}).

The monthly daily average global radiation values on the horizontal surface obtained from the Turkish State Meteorological Service for the period between 1991 and 2020 have been used in this research. The monthly

average daily global radiation data on the horizontal surface of Tekirdag and Konya provinces are given in *Figure 1*. Maximum monthly average daily radiation values on the horizontal surface in Tekirdag and Konya provinces are 5.97 kWh m^{-2} day^{-1} in June and 6.81 kWh m^{-2} day^{-1} in July, respectively.

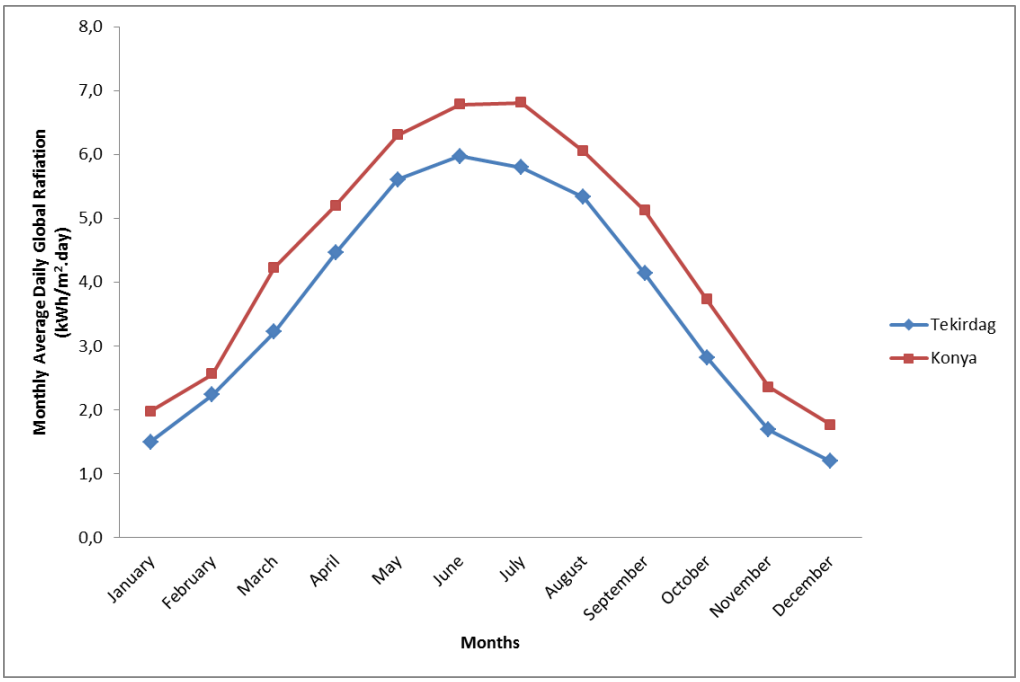


Figure-1. The monthly average daily global radiation values on the horizontal surface

In the model used in this study, two different equations (Eq. 6-7) have been developed depending on limit values of the sunset hour angle with clearness index.

At the boundary conditions $\omega_s \leq 81.4^o$ and $0.3 \leq \overline{K}_T \leq 0.8$;

$$\frac{\bar{H}_d}{\bar{H}_g} = 1.392 - 3.560\overline{K}_T + 4{,}189\overline{K}_T{}^2 - 2.137\overline{K}_T{}^3 \qquad \text{(Eq.6).}$$

At the boundary conditions $\omega_s > 81.4^o$ and $0.3 \leq \overline{K}_T \leq 0.8$;

$$\frac{\bar{H}_d}{\bar{H}_g} = 1.311 - 3.022\overline{K}_T + 3.427\overline{K}_T{}^2 - 1.821\overline{K}_T{}^3 \qquad \text{(Eq.7).}$$

In Eq6 and Eq7, $\bar{H}_d$ is the monthly daily average diffuse radiation on the horizontal surface (kWh m^{-2} day^{-1}).

The average monthly daily beam radiation on horizontal surfaces has been computed as follows (Eq. 8);

$$\bar{H}_b = \bar{H}_g - \bar{H}_d \qquad \text{(Eq.8).}$$

Where; $\bar{H}_b$ is the monthly daily average beam radiation on the horizontal surface (kWh m^{-2} day^{-1}).

The total amount of radiation coming to the tilted surface has been calculated using following equation (Eq. 9) (Liu and Jordan, 1960; Liu and Jordan, 1963);

$$\bar{H}_C = \bar{H}_b\bar{R}_b + \bar{H}_d\left(\frac{1+\cos\beta}{2}\right) + \bar{H}_g\rho_g\left(\frac{1-\cos\beta}{2}\right) \qquad \text{(Eq.9).}$$

Where; $\bar{H}_C$ is the monthly daily average total radiation on tilted surface (kWh m^{-2} day^{-1}), $\bar{R}_b$ is the geometric angle factor, β is the collector tilt angle and ρ_g is the surface reflection rate. Assuming that the tilted surface is on the ground, the reflection ratio (ρ_g) is taken as 0.14.

$\bar{R}_b$ for surfaces sloped towards the southern in the northern hemisphere is calculated by following equation (Eq. 10) (Yakup and Malik, 2001);

$$\bar{R}_b = \frac{\cos(\phi-\beta)\cos\delta\sin\omega_s' + \left(\frac{\pi}{180}\right)\omega_s'\sin(\phi-\beta)\sin\delta}{\cos\omega_s\cos\delta\sin\omega_s + \left(\frac{\pi}{180}\right)\omega_s\sin\phi\sin\delta} \quad \text{(Eq.10).}$$

Where; ω_s' is the monthly averaged daily mean sunset hour angle for the tilted surface and calculated as follows (Eq. 11);

$$\omega_s' = min\{\omega_s | \cos^{-1}(-\tan(\phi-\beta)\tan\delta)\} \quad \text{(Eq.11).}$$

In the above equation, whichever of the values to the left and right of the separator is smaller is taken as ω_s'.

For each month, the monthly average daily total radiation values coming to the tilted surface between 5 and 85 degrees with 5-degree intervals were calculated. With the help of the calculated monthly average daily radiation values, the monthly, seasonal and annual total radiation values on the tilted surface were calculated for each tilt angle. The tilt angles with the highest total radiation value on the tilted surface were accepted as the optimum tilt angle.

In addition, the regression relations between the monthly average daily total radiation values on the tilted surface ($\bar{H}_C$) and the angle of tilt (β) investigated. Among the models examined, the most appropriate one was the cubic regression model. In this model, it has been observed that there is a very close relationship between the total radiation on the tilted surface and the tilt angle (R^2=~1).

The Cubic regression equation (Eq. 12) is given below;

$$\bar{H}_C = a + b_1\beta + b_2\beta^2 + b_3\beta^3 \quad \text{(Eq.12).}$$

The coefficients in the Cubic regression model were calculated with the SPSS ver.18 package program.

Optimum monthly slope angles obtained by the derivative of the cubic regression model (Eq.12) were compared with the monthly optimum slope angles obtained from meteorological data (Eq. 13) (Jamil et al., 2016);

$$\frac{d}{d\beta}(\bar{H}_C) = 0 \quad \text{(Eq.13).}$$

3. Results and Discussion

The monthly daily average extraterrestrial radiation, beam and diffuse radiation values on horizontal surface and clearness indexes of two cities have been given in *Table 3*. It was observed that the clearness index was higher in Konya than Tekirdag in all months. While the clearness index was higher in the summer months in both provinces, it was lower in the winter months.

Table 3. The monthly daily average extraterrestrial, beam, diffuse radiation values (kWh/m^2.day) and clearness indexes

Month	Tekirdag				Konya			
	$\bar{H}_o$	$\bar{H}_b$	$\bar{H}_d$	$\bar{K}_T$	$\bar{H}_o$	$\bar{H}_b$	$\bar{H}_d$	$\bar{K}_T$
January	4.06	0.689	0.811	0.37	4.59	1.060	0.920	0.43
February	5.54	1.128	1.112	0.40	6.04	1.350	1.210	0.42
March	7.50	1.606	1.614	0.43	7.89	2.557	1.673	0.54
April	9.55	2.402	2.058	0.47	9.77	3.125	2.075	0.53
May	11.01	3.254	2.356	0.51	11.07	3.997	2.303	0.57
June	11.61	3.489	2.481	0.51	11.59	4.398	2.382	0.59
July	11.29	3.386	2.414	0.51	11.31	4.519	2.291	0.60
August	10.11	3.180	2.150	0.53	10.27	3.948	2.102	0.59
September	8.23	2.376	1.764	0.50	8.56	3.381	1.739	0.60
October	6.12	1.501	1.319	0.46	6.58	2.361	1.369	0.57
November	4.41	0.807	0.883	0.38	4.93	1.385	0.975	0.48
December	3.67	0.479	0.721	0.33	4.20	0.928	0.842	0.42

Monthly average geometric angle factors according to tilt angles in all months have been seen in *Figure 1*. Geometric angle factors were higher in summer than winter months. While the geometric angle factors decreased as the tilt angle increased in winter months, they increased up to 65-70 degrees tilt angle in summer months and started to decrease after.

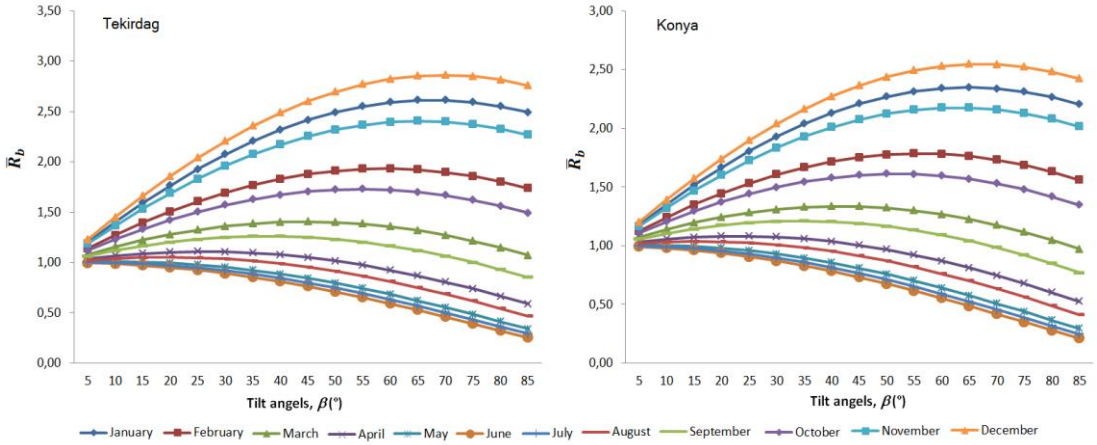


Figure 2. Monthly average geometric angle factors ($\bar{R}_b$)

Depending on the optimum tilt angles, the total radiation values coming to the tilted surface for each month are calculated and given in *Table 4*. Optimum tilt angles in all months were the same in both provinces. In Tekirdağ and Konya, the maximum monthly total radiation values on the tilted surface were 179.9 kWh m^{-2} $month^{-1}$ and 210.7 kWh m^{-2} $month^{-1}$, respectively, in July. Monthly total radiation values on tilted surface were higher in Konya province in all months.

Table 4. Monthly total radiation on tilted surface (kWh m^{-2} $month^{-1}$) and optimum tilt angles (°)

Months	Tekirdag		Konya	
	$H_{C,m}$	β_{ort}	$H_{C,m}$	β_{ort}
January	75.8	60	100.4	60
February	87.5	50	96.7	50
March	115.8	35	154.1	35
April	139.9	20	162.4	20
May	174.6	5	195.8	5
June	178.6	5	202.4	5
July	179.9	5	210.7	5
August	169.5	15	191.4	15
September	139.6	30	172.7	30
October	116.0	45	155.8	45
November	79.6	55	114.8	55
December	60.0	60	94.3	60
Total (kWh/m^2.year)	**1516.7**		**1851.4**	

Annual and seasonal total radiation on tilted surface at optimum tilts angles have been given *Table 5*. While the annual optimum tilt angles were different in the two provinces, the seasonal optimum tilt angles were the same. In Tekirdag province, the total radiation on tilted surface at annual and seasonal tilt angles decreased 4.5% and 0.8% according to monthly tilt angle, respectively. This decrease was 5.2% and 1.0%, respectively, in Konya province (*Figure 2*).

Table 5. Annual and seasonal total radiation on tilted surface (kWh m^{-2}) and optimum tilts angles (^{o})

City	Annual		Seasonal								
			Spring		Summer		Autumn		Winter		Total
	$H_{C,an}$	β_{ort}	$H_{C,sp}$	β_{ort}	$H_{C,sm}$	β_{ort}	$H_{C,au}$	β_{ort}	$H_{C,wn}$	β_{ort}	$H_{C,sea}$
Tekirdag	1448.4	25	424.4	20	526.0	5	331.0	45	222.8	55	1504.1
Konya	1754.7	30	503.1	20	603.0	5	436.9	45	290.5	55	1833.5

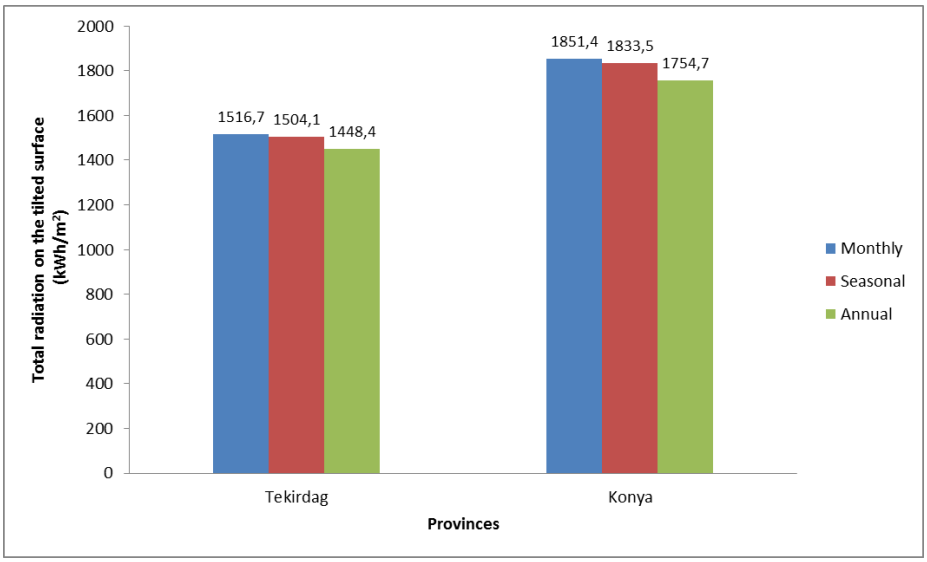


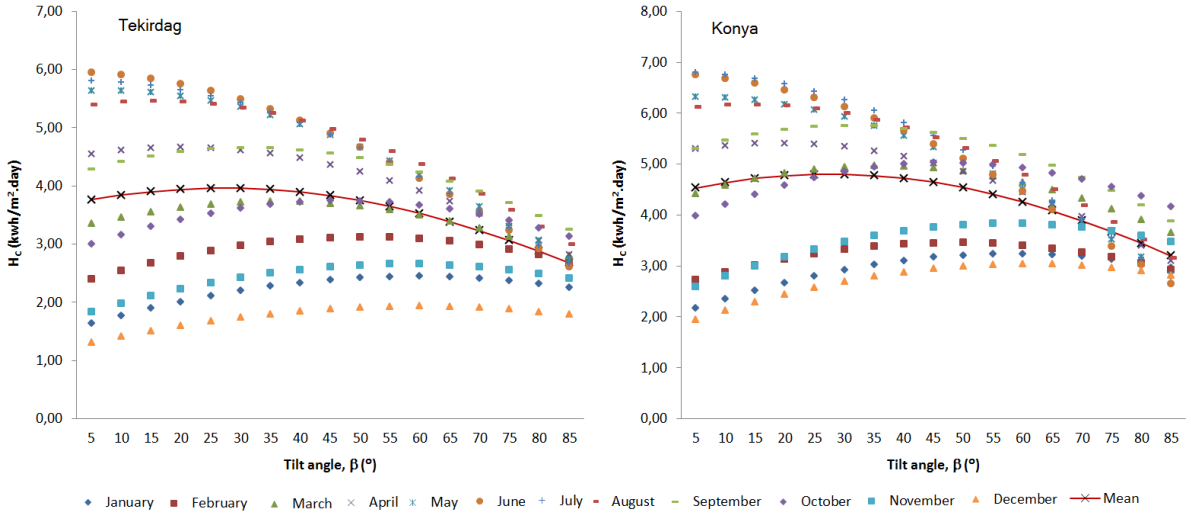
Figure 3. Monthly, seasonal and annual total radiation values on the tilted surface at optimum tilt angles.

In Tekirdag and Konya province, the Cubic regression model coefficients calculated for each month are given in *Table 6*. R^2 values of Cubic model were 0.999 in all months in both provinces. The distribution of the monthly daily average total radiation values on tilted surface according to the months depending on the tilt angles have been calculated by the Cubic regression model and given in the *Figure 3*.

Table 6. Coefficients of the Cubic regression model in Tekirdag and Konya

Month	Tekirdag				Konya			
	a constant	b_1	b_2 (x10^{-4})	b_3 (x10^{-7})	a constant	b_1	b_2 (x10^{-4})	b_3 (x10^{-7})
January	1.491	0.0306	-2.19	-4.11	1.968	0.0414	-3.04	-5.34
February	2.229	0.0345	-3.23	-2.07	2.547	0.0371	-3.73	-1.32
March	3.207	0.0300	-4.41	3.73	4.212	0.0428	-6.24	5.08
April	4.444	0.0225	-5.90	17.60	5.180	0.0256	-7.20	15.20
May	5.588	0.0114	-7.01	20.30	6.274	0.0107	-8.22	25.60
June	5.944	0.0039	-7.11	23.90	6.749	0.0017	-8.52	31.00
July	5.776	0.0073	-7.07	22.30	6.779	0.0063	-8.83	30.10
August	5.309	0.0212	-7.11	16.70	6.026	0.0223	-8.39	21.00
September	4.122	0.0348	-5.92	7.10	5.099	0.0441	-7.70	9.48
October	2.807	0.0393	-4.09	-1.05	3.711	0.0555	-5.81	-1.17
November	1.681	0.0324	-2.46	-3.97	2.345	0.0493	-3.75	-5.89
December	1.193	0.0236	-1.67	-3.29	1.759	0.0399	-2.74	-5.76
Mean	**3.649**	**0.0243**	**-4.86**	**7.65**	**4.387**	**0.0314**	**-6.19**	**9.87**

Optimum tilt angles calculated for each month with the meteorological solar radiation data and the cubic regression model are given in *Table 7*. The t-test was applied to investigate whether there is a difference between the total amounts of radiations coming to the tilted surface for each month at the optimum tilt angles obtained by the two methods. It has been observed that there is no statistically significant difference between the monthly



average daily radiation values on the tilted surface obtained by the two methods at optimum tilt angles in both provinces ($p>0.05$; $t=0.001$).

Figure 4. The monthly average daily total radiation values on tilted surface according to the months depending on the tilt angles

Table 7. Optimum tilt angles calculated with solar radiation data ($\beta_{opt,md}$) and the cubic regression model ($\beta_{opt,cm}$).

Months	Tekirdag		Konya	
	$\beta_{ort,md}$	$\beta_{ort,cm}$	$\beta_{ort,md}$	$\beta_{ort,cm}$
January	60	59.8	60	58.9
February	50	50.9	50	48.5
March	35	35.6	35	35.9
April	20	21.1	20	18.9
May	5	8.4	5	6.7
June	5	2.8	5	1.0
July	5	5.3	5	3.6
August	15	15.8	15	14.0
September	30	31.1	30	30.3
October	45	47.2	45	47.1
November	55	57.8	55	57.8
December	60	60.0	60	61.1
Annual	**25**	**26.7**	**30**	**27.1**

4. Conclusions

In this study, monthly, seasonal and annual optimum tilt angles and total radiation values on the tilted surface were determined by using meteorological data in the provinces of Tekirdag and Konya. In both provinces, it was observed that there was no significant difference in the total radiation values coming to the tilted surface in monthly and seasonal optimum tilt angles (~1%). At the annual optimum tilt angle, a decrease of approximately 5% was observed in the total amount of radiation coming to the tilted surface compared to the monthly optimum tilt angle. If solar energy systems with too many panels are taken into account, since the cost of adjusting the panels to the optimum tilt angle every month will be quite high, it will be more economical to adjust the tilt angles seasonal if possible. However, it is obvious that the cost of radiation losses on the tilted surface at the annual optimum tilt angles will be less than the monthly cost of adjusting to the optimum tilt angles. For this reason, it can be recommended to adjust the panel tilt angles to the annual optimum tilt angle in both provinces.

Depending on the tilt angles of the existing panel systems, the monthly average daily total radiation coming to the tilted surface can be estimated with the cubic model coefficients which are calculated in this study in both provinces. It is also possible to use these coefficients in software to be developed to estimate the total radiation amounts in panel systems in these provinces.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Research on the morphological and molecular diagnosis of *Hyalopterus pruni* (Geoffroy)

Hyalopterus pruni (Geoffroy)'nin morfolojik ve moleküler teşhisi üzerine araştırma

Esra TAYAT[1*], Nihal ÖZDER[2]

Abstract

Aphids are one of the most important groups of insects that cause damage to agricultural crops, ornamental plants, as well as herbaceous and woody plants in their natural habitats. Aphids that feed on plant sap can cause significant crop losses worldwide, ranging from 70% to 80%, due to stunted growth, deformation, wilting, and other detrimental effects on plants. Despite the chemical, biological, and integrated pest management methods applied against these damages, aphids have rapidly expanded their distribution areas and their damages have been increasing in recent times. *Hyalopterus* Koch (Hemiptera: Aphididae), a genus of aphids, are known worldwide as pests that infest *Prunus* trees, which are stone fruit trees. They cause damage by feeding on the trees and also by transmitting plant viruses. Subsequently, improper and indiscriminate use of chemical control methods negatively impacts both human and environmental health. Accurate identification of aphids, especially in terms of invasive species, is crucial for early detection of their damages in the initial stages. The mitochondrial cytochrome c oxidase subunit I (COI) gene is an effective gene region used in the identification of many economically important plant pests worldwide. In this study, a total of 50 individuals of *Hyalopterus pruni* (Geoffroy) were collected from three localities Şarköy (Ulaman, Bulgurlu, Gölcük, Cumhuriyet, Mürefte, Hoşköy, Gaziköy, Tepeköy, Palamut), Süleymanpaşa (Yüzüncüyıl, Altınova, Banarlı, Barboros, Bıyıkali, Çınarlı, Değirmenaltı, Ferhadanlı, Hürriyet, Karacakılavuz, Karaevli, Naip, Namık Kemal and Marmaraereğlisi (Bahçelievler, Cedit Ali Paşa, Dereağzı, Mustafa Kemal Paşa, Sultanköy, Türkmenli, Yakuplu and Yeniçiftlik) in Tekirdağ province. The species H11, H41, and H61, which were selected to represent three counties, were sequenced, and the molecular sequence results revealed that *H. pruni*, as morphologically described, showed 99% consistency at the molecular level.

Keywords: Aphid, *Hyalopterus pruni*, COI, Molecular diagnosis, Tekirdağ

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Öz

Yaprakbitleri tarım ürünleri, süs bitkileri, otsu ve odunsu bitkilere zarar veren en önemli böcek gruplarından biridir. Bitki özsuyu ile beslenen yaprakbitleri, bitkilerde bodulaşma, deformasyon, solma ve diğer zararlı etkileri nedeniyle dünya çapında %70 ila %80 arasında değişen önemli ürün kayıplarına neden olmaktadırlar. Bu zararlarına karşı uygulanan kimyasal, biyolojik ve entegre zararlı mücadele yöntemlerine rağmen yaprakbitleri son zamanlarda yayılma alanlarını hızla genişletmekte ve zararlarını arttırmaktadırlar. *Hyalopterus* Koch (Hemiptera: Aphididae) cinsine ait türler sert çekirdekli meyve ağaçları olan Prunus ağaçlarını istila eden zararlılar olarak dünya çapında bilinmektedir. Ağaçlarda beslenerek bitki virus vektörlüğü yaparak zarar verirler. Yaprakbitlerini doğru teşhisi, özellikle istilacı türler açısından, zararlarının başlangıç aşamalarında erken tespit için hayati öneme sahiptir. Yaprakbitleri taksonomistleri tür düzeyinde teşhisleri, konukçubitkilere dayalı tanı anahtarları kullanarak morfolojik özelliklere göre yapmaktadırlar. Bununla birlikte, yaprakbitleri gibi yüksek fenotipik çeşitliliğe sahip gruplarda, bu tanı anahtarları bazen yetersiz kalabilir. Mitokondriyal sitokrom c oksidaz alt ünitesi I (COI) geni, dünya genelinde birçok ekonomik öneme sahip bitki zararlılarının teşhisinde etkin kullanılan bir gen bölgesidir. Bu çalışmada, *Hyalopterus pruni* (Geoffroy) türünden toplam 50 birey, Tekirdağ ilindeki Şarköy (Ulaman, Bulgurlu, Gölcük, Cumhuriyet, Mürefte, Hoşköy, Gaziköy, Tepeköy, Palamut), Süleymanpaşa (Yüzüncüyıl, Altınova, Banarlı, Barboros, Bıyıkali, Çınarlı, Değirmenaltı, Ferhadanlı, Hürriyet, Karacakılavuz, Karaevli, Naip, Namık Kemal) ve Marmaraereğlisi (Bahçelievler, Cedit Ali Paşa, Dereağzı, Mustafa Kemal Paşa, Sultanköy, Türkmenli, Yakuplu ve Yeniçiftlik) bölgelerinden toplanmıştır. Üç ilçeyi temsil etmek üzere seçilen H11, H41 ve H61 türleri dizi olarak alınmış ve moleküler dizi sonuçları, morfolojik olarak tanımlanan *H. pruni'*nin moleküler düzeyde %99 uyumluluk gösterdiği tespit edilmiştir.

Anahtar Kelimeler: Yaprakbiti, *Hyalopterus pruni,* COI, Moleküler tanı, Tekirdağ

1. Introduction

Aphids are one of the most important insect groups that cause damage to agricultural products, ornamental plants, and naturally growing herbaceous and woody plants in the areas they are found. Aphids, which feed on plant sap, cause 70% to 80% crop loss worldwide due to consequences such as stunting, deformation, and wilting in plants. They are found worldwide, although they are more frequently observed in temperate zones (Blackman and Eastop, 2023). The aphids, which are significant pests of many plants, belong to the superfamily Aphidoidea (Hemiptera) (Budak et al., 2022). Species belonging to this superfamily generally live in colonies on their hosts (Zeybek and Tozlu, 2022). Certain aphid species pose a significant threat as invasive pests, jeopardizing agricultural ecosystems on a global scale (Capinera, 2002). They are not only plant feeders but also play a crucial role as virus vectors, responsible for transmitting nearly 30% of all known plant virus species (Brault et al., 2010).

The prominent biological characteristics of aphids, including polyphenism, host alternation, and the ability to reproduce both sexually and asexually, have rendered them a compelling model for evolutionary and ecological research. (Dixon, 1998; Coeur d'Acier et al., 2007). Furthermore, precise taxonomy is crucial for detecting biological invasions and effectively managing pest populations (Lozier et al., 2008).

Diagnoses of aphids are made using a single specimen and based on morphological characters, utilizing keys. Phenotypic variation due to host and environmental influences can make the diagnosis of aphids difficult. Furthermore, other factors that can make the diagnosis of aphid species difficult include the occurrence of different morphologies on different hosts under various climatic conditions, complex life cycles, polymorphism, cyclic parthenogenesis, and host switching during summer and spring months. Considering these factors, a potentially more dependable method for diagnosing taxonomically complex groups could be to collectively assess morphological, molecular, and host plant information (Hebert et al., 2003).

The mitochondrial cytochrome c oxidase sub unit I (COI) gene has been widely adopted as an effective method for the identification of many economically important plant pests worldwide. Mitochondrial gene regions include cytochrome oxidase I and II (COI, COII), cytochrome b (CytB), F-ATPase subunits 6 and 8 (F-ATP), NADH-1 dehydrogenase (NADH1), and 12S and 16S ribosomal RNA (12S/16S). (Hoy, 2003); (Freeland, 2005). COI has two important advantages among these gene regions. Firstly, universal primers for this gene region are highly robust. Secondly, it has more phylogenetic markers compared to other mitochondrial genes. Furthermore, it is observed that the amino acid sequence changes are relatively slow (Hebert et al., 2003). It has been reported that the COI region is useful for the accurate identification of aphid species, especially in cases where morphological characters are insufficient (Cocuzza et al., 2015).

Accurate and timely identification of *Hyalopterus* members is essential for proper and timely control, as well as reducing the economic losses they cause. In all molecular and morphometric studies conducted on this genus in recent years, it has been widely accepted that members of this genus use different *Prunus* species as their primary host (Poulios et al., 2007, Lozier et al., 2008; Rakauskas et al., 2013). Especially with their primary hosts being economically important *Prunus* spp. species, aphids cause direct damage and result in economic losses. The differentiation of members of this genus is challenging because their identification is solely based on corniculus in the morphological key (Lozier et al., 2008; Rakauskas et al., 2013). In additionally, *Hyalopterus pruni* has been detected in approximately 32 provinces in Turkey and is a seriously spreading aphid species (Kök and Özdemir, 2021).

Hyalopterus pruni apterae rather elongate-bodied, pale green with darker green mottling, covered with white wax meal; BL 1.5-2.6 mm. On undersides of leaves of *Prunus domestica*, and sometimes on other *Prunus* spp., especially *P. armeniaca*, but not *P. dulcis*. Infested leaves do not curl. Alatae have a green abdomen with white wax patches on each segment. Migration occurs to *Phragmites*, or sometimes to *Arundo donax*; for its appearance on *Phragmites* see. Widely distributed in Europe and Asia and introduced to North America, but records from Africa and Australia are based on secondary host populations and are possibly another species (Blackman and Eastop, 2023).

2. Materials and Methods

2.1. Collection and preparation of aphids

The survey study was conducted in Şarköy, Marmaraereğlisi and Süleymanpaşa province of Tekirdağ in 2021. The aphids samples were collected from plum (*Prunus domestica*) trees.

During sampling, attempts were made to collect as many winged and wingless adult individuals as possible. A code number has been assigned to each sample. Furthermore, information such as the color prior to preservation in alcohol, date, host plant, and collection location were recorded in the field notebook. The generated code numbers were placed as labels, written with a pencil, inside the cryo tubes containing the aphid samples.

The collecting and preservation methods employed were largely based on Hille Ris Lambers (1950) approach. According to this method, aphids were initially subjected to the cleaning process to reveal diagnostic characteristics and to remove body colors and waxy substances present on the body in some species. Sufficient 4 minutes below the boiling point in a water bath. The ethyl alcohol in the tubes was emptied, and 10% KOH was added to the tubes. The specimens, especially the dark-colored ones, were boiled in KOH for 3-7 minutes until their colors became suitable. After determining sufficient lightening of the specimen colors, ethyl alcohol was added to the glass tubes containing KOH, and then they were left to stand for a while. Subsequently, the KOH-ethyl alcohol mixture was removed from the tubes manually or with the help of a pasteur pipette. Ethyl alcohol was added again to the tubes to ensure thorough cleaning of the specimens. The ethyl alcohol in the tubes was emptied, and a previously prepared 1:1 mixture of Chloral hydrate-Phenol was added to the tubes. The samples were kept in this mixture at temperatures below the boiling point in a water bath, varying depending on the species, for 5-10 minutes. After the cleaning process, the aphid samples were thus made ready for preparation. The preparation process of the cleaned aphids was completed. The Berlese medium was used as the environment for preparing permanent mounts. To prepare this medium, a specific amount of gum arabic, glycerin, chloral hydrate, and distilled water were thoroughly mixed at room temperature and then filtered through several layers of glass wool to obtain a clean mixture. After preparing the Berlese medium, a small amount was dropped onto each slide, and the cleaned aphids were placed on each slide in both ventral and dorsal positions, as nymphs and winged-wingless adults. The aphids placed on the slide were positioned with their antennae, wings, and legs open, ensuring that diagnostic characteristics were visible.

2.2. Morphological characterization of aphids

The diagnoses of *Hyalopterus pruni* samples obtained from their host plants in Tekirdağ province during field studies conducted in 2021 were morphologically carried out according to Cottier (1953), Börner (1952), Bodenheimer and Swirski (1957), Hille Ris Lambers (1945, 1947a, 1947b, 1949, 1969, 1973), Börner and Heinze (1957), Tuatay and Remaudiere (1964), Shaposhnikov (1964), Stroyan (1957, 1961, 1963, 1969, 1977, 1984), Bissel (1978) and Blackman and Eastop (1984, 1994, 2000, 2014, 2020). The species identification of aphids was carried out using a LEICA DM LB2 light microscope. The definite identification of aphids was performed by Associate Professor Dr. Işıl ÖZDEMİR.

2.3. DNA extraction, amplification and sequence

A total of 50 individuals of *H. pruni* were collected from three localities Şarköy (Ulaman, Bulgurlu, Gölcük, Cumhuriyet, Mürefte, Hoşköy, Gaziköy, Tepeköy, Palamut), Süleymanpaşa (Yüzüncüyıl, Altınova, Banarlı, Barboros, Bıyıkali, Çınarlı, Değirmenaltı, Ferhadanlı, Hürriyet, Karacakılavuz, Karaevli, Naip, Namık Kemal and Marmaraereğlisi (Bahçelievler, Cedit Ali Paşa, Dereağzı, Mustafa Kemal Paşa, Sultanköy, Türkmenli, Yakuplu and Yeniçiftlik) in Tekirdag province. DNA extraction was done following method; Put the aphid in a 1.5 ml Eppendorf tube. If the aphid was stored in ethanol, place the aphid on a tissue for a few minutes to let the ethanol evaporate. Wash pestle in a large volume of distilled water and dry after every use. Add 300 µl TNES buffer by letting it run down the pestle to wash all of the squised aphid into the tube. Mix and incubate tube at 55 °C for 1 – 3 h (or at 37 °C over night). Add 85 µl of 5M NaCl and shake hard for 15 s (proteins become precipitated). Microfuge at full speed for 5 – 10 min. Microfuge at full speed for at least 5 min. Air-dry the pellet cover tubes with a tissue to avoid contamination. Re-suspend the DNA in the required amount of 1x TE buffer.

A 700 bp segment of the mitochondrial COI gene was PCR amplified using the primers LepF (5′-

ATTCAACCAATCATAAAGATATTGG-3′) and LepR (5′-TAAACTTCTGGATGTCCAAAAAATCA-3′) (Hebert et al. 2004). The PCR assay was carried out following program initial denaturation at 94°C for1 min, followed by 6 cycles of 1 min denaturation at 94°C, 1 min and 30 s annealing at 45°C, and 1 min and 15 s extension at 72°C, then followed by 36 cycles of 1 min at 94°C, 1 min and 30 s at 51°C, and 1 min and 15 s at 72°C, with a final step of 5 min extension at 72°C, and cooling to 4°C before the PCR products were removed from the thermocyler. PCR products were checked by electrophoresis on 1.5% agarose gel in TBE buffer (*Table 1*) (Xu et al., 2011).

Table 1. Chemicals used for polymerase chain reaction (PCR).

for 10 µl reactions	
H2O	4.0 µl
10 × Taq buffer	1.0 µl
MgCl2 25 mM	0.8 µl
dNTPs	1.6 µl
Forward primer	0.5 µl
Reverse primer	0.5 µl
Taq polymerase	0.1 µl
DNA	1.0 µl

Additionally, three samples representing each district were selected and sent to the Nabiltem Center Laboratory at Tekirdag Namik Kemal University for sequencing.

2.4 Data analysis

The sequence results were aligned using MEGA 4 (Tamura et al., 2007) and identified by comparison with the nucleotide-nucleotide basic alignment search tool (BLAST) (GenBank DNA sequence database, National Center for Biotechnology Information).

3. Research Results and Discussion

Identify aphids using mitochondrial genes, PCR was done using LepF and LepR primers. The PCR products showed a 700 bp band segment as mentioned amplifying DNA fragment of the mitochondrial genome in all samples. To sequence the mitochondrial gene, PCR products were sent to NABILTEM Center Laboratory. After sequencing, results were aligned, and the gene-related sequence was blasted in NCBI GenBank. Based on the BLAST results, the samples were identified. >99% identity and 100% coverage to: *Hyalopterus pruni* (KR582302). H11, H41, and H61 (species representing thee different locations of Tekirdag) are matching. The gene is confirmed as "COI". The size that we could successfully recover is ~340 bp.

The morphological characteristics of aphids play a significant role in their ability to adapt to different host plants. Furthermore, environmental factors such as day length and temperature have complex effects on the morphological characteristics used to identify population differences. The morphology of aphids and their relationship with host plants are crucial in their classification. Their ability to closely associate with host plants relies on their distinct life cycles (Lee et al., 2015). The mitochondrial COI gene region is important in revealing the genetic variation at the species and interspecies levels in aphid groups, due to its rapid and highly accurate results (Foottit et al., 2009; Valenzuela, 2009).

In recent years, DNA barcoding studies have become one of the frequently used methods by many aphidologists to address taxonomic issues in various insect groups, including aphids, aiming to resolve existing taxonomic problems. (Hebert et al., 2003). Lozier et. al. (2008) before updating the diagnostic key used for distinguishing members of the genus Hyalopterus, it has been reported that often *H. amygdali* or *H. pruni* were indicated when it came to the genus discrimination in the diagnostic key, and these two species were frequently confused with each other during diagnosis.

In their study conducted in Greece, Poulios et al. (2007) determined that *H. amygdali* A utilizes *P. dulcis* and *P. armaniaca* as hosts, *H. amygdali* B utilizes *P. persica* as a host, and *H. pruni* utilizes *P. domestica* as a host. Indeed, in our study, samples were collected from *P. domestica*, and both classical and morphological analyses confirmed that they were *H. pruni.* Lozier et al. (2008) evaluated *Hyalopterus* populations feeding on *Prunus* host

plants in Spain, Italy, Greece, Tunisia, Israel, the United States, and Georgia using molecular methods in their study. They have determined that *H. persikonus* feeds on *P. persica*, *H. amygdali* feeds on *P. dulcis*, and finally *H. pruni* feeds on *P. domestica*. In his study conducted in Afyonkarahisar, Kütahya, Niğde, and Uşak provinces, Şenol (2017) sampled from different localities on *P. domestica*, *P. persica*, *P. dulcis*, *P. armaniaca*, and *Phragmites* hosts. It has been determined that the morphological variations of individuals belonging to the genus *Hyalopterus*, depending on the host, locality, and species, are consistent with previous studies.

4. Conclusions

Species definitions derived from traditional diagnostic methods could potentially be deceptive, particularly within categories like aphids. As a result, it is recommended to collectively analyze morphological and molecular data before attempting species identification in the investigated aphid groups.

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