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# Analysis of Factors Affecting Potato Growing Decisions of Farmers: The Case of Ödemiş District of İzmir Province

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**ABSTRACT**

The aim of this study is to determine the factors affecting the potato growing decisions of the farmers in Ödemiş district of İzmir province. In the study, data were collected from 90 farmers by proportional sampling method and face-to-face survey method. The production period of 2019 was included in the scope of the study. In the analysis of th,e data, first the socio-economic characteristics of the farmers were examined, then the criteria that the farmers gave importance to in their potato production decisions and the economic aspects of potato production were analyzed. Five-point Likert scale and Fuzzy Paired Comparison method were used in the analysis of farmers decisions. According to the results of the study, the average age of the farmers is 52.49 years and the average education period is 8.29 years. The most important criterion in potato production is price. Average potato production area is 4.19 hectares. The average yield obtained from potato production per hectare was determined as 38,758 kg. Average potato price received by the farmer was 1.43 TL kg. The average net profit from potatoes per hectare was calculated as 22,720 TL. Farmers want to sustain potato production. For this, effective potato policies should be prepared, farmers should be supported and Turkey should be self-sufficient in potato production.

## 1. Introduction

Different purposes can be taken into account in determining the crop pattern in farms. Farmers aim to provide the highest income while determining the crop pattern. However, they also have to take into account natural, economic and political conditions. However, in some cases, farmers can direct their production according to their knowledge level and habits (Işın, 2001). The products grown by the farmers on irrigable lands can also change over time and under the influence of various conditions. For example, it is seen that farmers prefer products that require less water in dry periods, products with low cost in times of economic crisis and high input prices, and products that require less labor in times of labor force problems. In addition, the product selections of the farmers may vary from region to region. The products mostly grown by the farmers in irrigated lands of İzmir province are cotton, potato, tomato, cucumber, pepper, green beans, watermelon, wheat, corn and some forage crops.

Potatoes are mostly grown as the main product in Turkey, and in the Mediterranean and Aegean regions, they are also grown for winter use for the purpose of early-season potato. The most important advantage of early-season potato growing is that farmers can provide high income in winter when alternative crops are scarce (Samancı et al., 2003). According to TURKSTAT data, 5.2 million tons of potatoes were produced on 147,993 hectares of land in Turkey in 2020. Average potato yield is 35,137 kg per hectare. Considering the distribution of potato production by provinces; Niğde (13.3%) ranks first, Konya (12.3%) second, Afyon (10.6%) third, Kayseri (10.4%) fourth and İzmir (8.4%) fifth (TURKSTAT, 2021).

It is seen that many studies have been carried out on the economic aspects of potato cultivation in Turkey so far (Karadaş, 2000; Özdemir, 2003; Şahin, 2003; Uzundumlu, 2005; Yılmaz et al., 2006; Birinci and Küçük, 2006; Engiz, 2007; Engindeniz and Karakuş, 2008; Tok and Davran, 2010; Bağcıtek, 2017; Karsan and Gül, 2017; Örmeci Kart et al., 2017; Kılıçer, 2019; Yücel and Oğuz, 2020; Kadakoğlu and Karlı, 2021). However, the fluctuations in potato prices in recent years have brought

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up the importance of this issue and that it should be researched. When potato prices increase in Turkey, the adoption of imports instead of solving the problems arising from production causes these problems to continue increasingly (Yegül, 2020). For this reason, it is necessary to reveal the farmer's decisions and the factors affecting them.

Many factors can be effective in determining the crop pattern and crop rotation system of the farmers. Therefore, the changes that may occur over time should be closely followed in the farmer's conditions. In this way, local production resources can be used efficiently, as well as increasing the income of farmers and preparing production plans. In addition, researches to be conducted in this direction will reveal the problems encountered and shed light on the determination of the most appropriate agricultural policies to be applied.

The aim of this study is to determine the factors affecting the potato growing decisions of the farmers in Ödemiş district of İzmir province. Some solutions for the problems encountered in the study are also presented.

## 2. Materials and Methods

The data constituting the main material of the research were obtained by face-to-face survey method from farmers engaged in potato (main product) growing in Ödemiş, İzmir. Apart from this, the agricultural data of the relevant organizations and the findings of previous researches were also used.

According to the information received from the Ödemiş District Directorate of the Ministry of Agriculture and Forestry, approximately 85% of the potato production in İzmir is the Ödemiş district and the majority of the potato production in the district is Bozdağ, Gölcük, Çaylı, Cumhuriyet, Umurbey, Yolüstü, Üçeylül, Gereli, Yolüstü and Karakova. carried out in the neighbourhoods. Therefore, these neighborhoods were included in the study. The total number of farmers registered in the Farmer Registration System in these neighborhoods was determined as 1,242, and these farmers constitute the main population of the study.

In the research, some of the farmers were included in the scope by sampling method. At this stage, the following Proportional Sampling Formula was used (Newbold, 1995). As a matter of fact, it is seen that this formula is used in the sampling phase of many studies (Çobanoğlu et al., 2005; Kızılaslan and Somak, 2013; Çakır et al., 2015; Erdoğan and Gökdoğan, 2017; Barlas et al., 2019; Akboğa and Pakyürek, 2020).

$$n = \frac{Np(1-p)}{(N-1)\sigma_{p_x}^2 + p(1-p)}$$

In the formula;
$n$ = Sample size
$N$ = Total number of farmers
$p$ = Proportion of farmers growing potatoes (0.5 for maximum sample size)
$\sigma_{p_x}^2$ = The variance of the ratio.

In the study, the 95% confidence interval and 10% margin of error were taken as basis and the sample size was calculated as 90. In determining the number of farmers to be interviewed in each neighborhood, the ratios of the neighborhoods to the total number of farmers were taken into account. The farmers interviewed in the neighborhoods were determined by using the random numbers table. The research was based on the 2019 production period and survey studies were carried out in the January-February 2020 period.

In the study, first of all, the socio-economic structures of the farmers were analyzed. For this purpose, age, education level of farmers, family population, land characteristics and use, family labor potential, capital structure and organizational characteristics were examined. Then, the factors affecting the farmers' decisions to grow potatoes and the results of their activities were analyzed.

In the economic analysis of potato production, input usage levels, yield levels, product prices, production costs and net profits were determined. In potato production, labor and towing costs and material (pesticide, water, seeds, fertilizer, etc.) costs are the variable cost elements, while the land rent, the interest of the total variable costs and the administration cost are the fixed costs. The interest for the total variable costs is calculated based on half of Ziraat Bank's agricultural loan interest rate (10%). The administration costs was determined by taking 3% of the total variable costs (Kıral et al., 1999).

Labor costs were calculated by adding the equivalent of family labor to the payments made for temporary labor in farms. Material costs were determined based on the amount of inputs used and the current prices paid. In order to ensure homogeneity, the unit soil preparing costs (tool-machine rent) in the region were taken into account in the determination of the machine costs (Tanrivermiş, 2000; Birinci and Küçük, 2004; Özkan et al., 2005; Aydın Can and Yercan, 2006; Engindeniz and Öztürk Coşar, 2013). Turkish Lira (TL) was used as the currency in the study. 1 USD was equal to 5.68 TL in 2019.

In the study, the factors that the farmers attach importance to in their agricultural production decisions and their future goals are analyzed. At this stage, a five-point Likert scale was used.

The Fuzzy Paired Comparison method was used in the analysis of the criteria that producers give importance to in their potato production decisions. In this study, six different criteria were presented to farmers for determining the decision choices. These criteria were price, cost, government support, yield level, climatic conditions and soil characteristics. Method steps may be summarized as follows (Zadeh 1983; Ross, 1995; Klir and Yuan, 1995; Tanaka, 1997; Pedrycz and Gomide, 1998).

First, pairwise comparisons were presented to indicate individual preferences. The total distance in comparison is follow equal.

If GKH=0.5 then K≈H; if GKH>0.5 then K>H and if GKH<0.5 then K<H.

The number of paired comparisons of the objectives (C) were determined as C= [(Z*(Z-1))/2]. Z refers to preferred number of objectives in the formula.

In this study, 15 comparisons of six different criteria were presented to each individual. For each pairwise comparison, gcr preference was obtained. Measurement of the preference degree of r according to c can be expressed as gcr=1-grc. Then, fuzzy preference matrix was as follow generated as follow;

$$G_{cr}=\begin{cases}0 & if\ \ c=r\ \ \forall\, c,r=1,\dots.n\\ g_{cr} & if\ c\neq r\ \forall\, c,r=1,\dots..n\end{cases}$$

In this study, 6x6 fuzzy preference matrix was created for each individual as follow (G);

$$G=\begin{vmatrix}0 & g_{12} & g_{13} & . & . & g_{1r}\\ g_{21} & 0 & . & . & . & .\\ g_{31} & g_{32} & 0 & . & . & .\\ . & . & . & 0 & . & .\\ . & . & . & . & 0 & .\\ g_{c1} & . & . & . & . & 0\end{vmatrix}$$

Separately preferred density of each objective (μj) was obtained using the following equation;

$$\mu_j=1-\left(\sum_{c=1}^{n} G_{cr}^{2}/(n-1)\right)^{1/2}$$

The value of μj ranges between 0 and 1. The purpose of the comparison was determined whether they are equally important using Friedman Test. Furthermore, Kendall's coefficient of concordance for ranks was used.

## 3. Results and Discussion

Some socio-economic characteristics of potato farmers are presented in Table 1. The average age of the farmers was 52.49 years and the average education period was 8.29 years. The average household size is 3.80 people. Men constitute 54.21% of the total population. When examined in terms of age, it was determined that 53.42% of the population was 15-49 years old, and 30.53% were 50 and older people.

Table 1
Socio-economics characteristics of potato farmers

| Variables | Mean |
|---|---|
| Age of farmer | 52.49 |
| Education level of farmer (year) | 8.29 |
| The experience of the farmers in growing potatoes (year) | 24.44 |
| Household size | 3.80 |
| Land size (ha) | 5.11 |
| Family labor potential | 2.54 |
| Equity capital rate (%) | 93.24 |
| Cooperative rate (%) | 88.89 |

The average family labor potential was determined as 2.54 as unit of male labor. 49.69% of the family labor potential consists of male population. In terms of age; 70.47% of the population is between the ages of 15-49. In the farms, 58.95% of the family labor potential is used in potato production. The experience of producers in potato production was found to be 24.44 years on average.

The average land size in the farms was determined as 5.11 hectares. The average parcel number is 4.86, and the average parcel size is 1.05 hectares. 92.19% of the farm lands are cultivated by the owner. On average, 95.54% of the lands are irrigated. Land capital constitute 88.66% of the total active capital, and equity capital constitutes 93.24% of the total passive capital. It has been determined that 88.89% of the farmers are partners in any agricultural cooperative. The most common cooperative is the Agricultural Credit Cooperatives.

The factors that they give importance to when making decisions in agricultural production were asked to the farmers and the level of importance was examined. Factors that farmers consider the most important at this stage; market conditions and price changes, as well as the level of profitability and sustaining the activity (Table 2).

Table 2
Factors that farmers give importance to in the decision of agricultural production

| Factors | Level of importance* |
|---|---|
| Level of knowledge about agricultural activity | 4.41 |
| Choosing the area of production | 4.39 |
| Profitability level and sustaining the activity | 4.48 |
| Market conditions and price change | 4.50 |
| Personal disposition and preferences | 4.37 |
| Total costs | 4.40 |

*1. Not at all important, 2. Not important, 3. Undecided, 4. Important, 5. Very important

Fuzzy Paired Comparison method was used to analyze the factors affecting the farmers' decision on potato production. Farmers were asked to compare price, cost, soil characteristics, yield level, climatic conditions and government support bilaterally. Fuzzy Paired Comparison method results are given in Table 3. Influencing factors are listed according to their weights, from largest to smallest. It has been determined that the most important factor for the farmers to decide on potato production is the price. Other important factors are cost, government supports, yield level, climatic conditions and soil characteristics, respectively. According to the Friedman test results, the difference between the preferences is statistically significant. It can be said that some factors related to the production decisions of the farmers are preferred over the others.

Table 3
Fuzzy Paired Comparison method results

| Factors | Mean | Std. error | Min. | Max. |
|---|---|---|---|---|
| Price | 0.655 | 0.140 | 0.300 | 0.900 |
| Cost | 0.640 | 0.109 | 0.397 | 0.874 |
| Government support | 0.445 | 0.144 | 0.139 | 0.759 |
| Yield level | 0.423 | 0.089 | 0.228 | 0.615 |
| Climatic conditions | 0.276 | 0.090 | 0.100 | 0.776 |
| Soil characteristics | 0.233 | 0.070 | 0.119 | 0.482 |

Friedman test is significant for p<0.01. Kendall's W: 0.703

Considering the values of Kendall's W test, it can be said that the fit is very weak (0.1), weak (0.3), moderate

(0.5), strong (0.7), and strongly strong (0.9). Kendall's W value was found to be 0.703 in the study. While determining the weights of the important criteria, the agreement between the producers is strong (Table 3).

60% of farmers used loans for potato production. farmers mostly used enterprise and investment loans from Ziraat Bank. When the farmers were asked whether they received support from the state, 24.44% stated that they did not. Supported farmers mostly benefited from diesel-fertilizer support. 61.11% of the farmers stated that they found the state supports very insufficient, 34.44% insufficient.

When the farmers were asked about their level of knowledge on organic potato production, 36.67% of them stated that they had knowledge. 27.78% of farmers consider producing organic potatoes. On the other hand, 42.22% of the farmers stated that they had knowledge about good agricultural practices. 27.78% of farmers consider producing potatoes with good agricultural practice.

38.9% of the farmers have a positive attitude towards contract production and want to make contract production. When the farmers were asked whether they had insurance in potato production, only one farmer stated that he had insurance for his potatoes.

The results for the economic analysis of potato production in the farms included in the study are presented in Table 4. Average potato production area in farms is 4.19 hectares. Potato yield per hectare varies between 30,000 and 43,000 kg. Average potato yield per hectare was calculated as 38,758 kg. According to the studies carried out in different regions in Turkey, it is seen that the potato yield per hectare varies according to the regions. For example, in a study conducted in İzmir, 25,870 kg (Özdemir, 2003), in a study in Nevşehir 52,800 kg (Engiz, 2007), in a study in Tokat 24,500 kg (Yıldırım et al., 2019), in Bitlis It was found to be 32,800 kg in a study (Şahin, 2003), and 15,790 kg in a study conducted in Erzurum (Birinci and Küçük, 2006).

Table 4
Economic analysis of potato production

| Variables | Mean |
|---|---|
| 1.Potato production area (ha) | 4.19 |
| 2.Verim (kg ha) | 38,758 |
| 3.Price received by the farmer (TL kg) | 1.43 |
| 4.Gross production value (TL ha) (2x3) | 55,424 |
| 5.Variable costs (TL ha) | 26,722 |
| 6.Total production costs (TL ha) | 32,704 |
| 7.Unit cost (TL kg) (6/2) | 0.84 |
| 8.Gross profit (TL ha) (4-5) | 28,702 |
| 9.Net profit (TL ha) (4-6) | 22,720 |
| 10.Relative profit (4/6) | 1.69 |

In the farms examined, 79.27% of the potatoes were marketed to merchants, 9.12% to brokers, 7.312% to potato processing companies and 4.30% to consumers directly. Again, in a study conducted in İzmir, it was determined that 97.73% of it was marketed to merchants and 2.27% to processing companies (Özdemir, 2003). The price of potatoes received by the famers varied between 0.85-2.00 TL kg. The average price is calculated as 1.43 TL kg. In a study conducted in the province of Niğde in the same period, it was determined that the price ranged between 0.6-1 TL kg (Kılıçer, 2019).

The average production cost per hectare for potatoes in the examined farms was calculated as 32,704 TL. Material costs account for 46.99% of production costs, labor and machine costs 34.72%, and other costs account for the remaining 18.29%. As can be seen, 81.71% of production costs in farms are variable costs. The ratio of variable costs to production costs; it was found to be 83.6% in Niğde (Karsan and Gül, 2017), 92.17% in Erzurum (Birinci and Küçük, 2006), 91.93% in Tokat (Yıldırım et al., 2019), and 85.67% in Nevşehir (Engiz, 2007).

The average kg cost of potatoes in the examined farms was determined as 0.84 TL. In a study conducted in Tokat in the same period, the unit cost was determined as 1.54 TL kg (Yıldırım et al., 2019). In a study conducted in Niğde, it was determined that the unit potato cost of 42.2% of the farmers was 0.41-0.60 TL kg, and the unit potato cost of 34.1% was 0.61 TL kg and above (Kılıçer, 2019).

The average gross production value of potato per hectare was determined as 55,424 TL, average gross profit per hectare 28,702 TL, and average net profit per hectare 22,720 TL in the examined farms. In a study conducted in Bitlis, it was determined that variable costs constitute 57% of the gross production value (Şahin, 2003), and in a study conducted in İzmir, it was determined that the farmers could not even meet the variable costs and incur losses (Özdemir, 2003).

The problems faced by the farmers in production and marketing are summarized in Table 5. They stated increases in input prices, fluctuations in potato prices, and inadequacy in support and organization as the most important problems. It is necessary to increase the sustainability of potato production in the region with short and medium-term measures to be taken for these problems.

Table 5
Problems faced by farmers in potato production and marketing

| Problems in production | Problems in marketing |
|---|---|
| Increases in input prices | Fluctuations in potato prices |
| Insufficient support for potatoes | Problems in wholesaler organization and interruptions |
| Problems in the supply of seeds | Organizational deficiencies |
| Problems in fertilizer use | Inadequacy of processing facilities |
| Problems in pesticide use | Failure to develop contract farming |
| Problems in irrigation | Failure to produce for export |
| Negative effects of climate change | Inadequacy of cold storage |
| Insufficiencies in extension efforts | Product sales that could not be collected on time |

The farmers were asked about their future goals regarding agricultural production and their participation levels were examined. The most important goals of the farmers regarding agricultural production; preserving the land and capital and transferring it to future

generations, sustaining potato production and producing at the lowest cost (Table 6).

Table 6
Future goals of farmers regarding agricultural production

| Future goals | Level of participation* |
|---|---|
| Preserving land and capital, and transferring it to future generations | 4.50 |
| To produce at the lowest cost | 4.48 |
| Sustaining potato production | 4.48 |
| Reducing risks in production and marketing | 4.47 |
| Pay off debts | 4.47 |
| Implementing innovations and increasing profits | 4.42 |
| Using more technology | 4.41 |
| Sustaining family labor use | 4.41 |
| Buying new tools and equipment | 4.39 |
| Expand the farm land | 4.39 |
| Start a new farm | 4.37 |
| Using organic and environmentally friendly methods | 4.32 |

*1.Strongly disagree, 2.Disagree, 3.Undecided, 4.Agree, 5.Strongly agree

## 4. Conclusion

According to the results of the study, market conditions and price changes were determined to be the most important factors for farmers in agricultural production. The most important criterion for the farmers to decide on growing potatoes is the price. Potato price recieved by the farmers in the examined farms varied between 0.85-2.00 TL kg. Average price is calculated as 1.43 TL kg. Farmers earn a net profit of 22,720 TL per hectare from potato growing. Farmers are considering sustaining their potato production in the future. However, they also expect solutions for the problems they encounter. For this, effective potato policies should be prepared, farmers should be supported and Turkey should be self-sufficient in potato production.

The biggest expectation of potato farmers is a sustainable and planned production. In order for the farmers to continue their potato production and to transfer this production branch to the next generations, their current problems should be solved in the short term. In particular, potato imports should not be seen as a solution and domestic production should be supported by planning. For this, first of all, a potato map should be created to determine how much and in which region the farmers will produce, the product should be guaranteed and the production amount to meet the country's needs should be planned.

One of the most important problems encountered in potato production is marketing. A regular market structure in potato production in Turkey not available. In order to prevent product losses and seasonal fluctuations, a production plan should be made, and diversity in production and processing should be ensured by integrating food and industry. In this way, supply fluctuations can be prevented.

Potatoes in Turkey; It is one of the products with the most fluctuations in price. The reason for this can be shown as environmental and climatic conditions and costs. In some periods, the amount of product supplied to the market is high, which causes the price to decrease in that period. In some periods, the quantity supplied is low and the price increases. Policies should be developed to prevent price instability.

Organization should also be utilized in solving the problems of potato farmers regarding input supply and marketing. Farmers especially need to be organized in the form of cooperatives. Cooperatives should take an active role in the production and marketing of quality products in accordance with market conditions.

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# The Toxic Effects of Lead on Seedling Growth Development of *Euphorbia Hirta* Forsk (Weed) and *Sporobolus Coromandelianus* (Retz.) Kunth (True Grass)

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**ABSTRACT**

Lead is considered a toxic heavy metal and released in the air, water and soils due to auto wheels, industrial and anthropogenic activities which influence on plant growth, fauna and environment. It is hypothesized that plants are capable of showing different responses of toxicity and tolerance to metals stresses. The objective of this study is to investigate the influence of one of the highly toxic heavy metal, lead (Pb) on the seedling growth of native plant species, *Euphorbia hirta* Forsk and *Sporobolus coromandelianus* (Retz.) Kunth in pots as there are very few data available in the literature on this toxicity subject. It is important to compare both genotype under various level of lead treatment. The seedlings of *E. hirta* and *S. coromandelianus* showed different effect when treated with 20, 40, 60, 80, 100 as compared without 0 ppm concentrations of lead. The results of the present studies showed the statistically significant ($p<0.05$) influences of lead 40 ppm treatment on number of leaves, leaf area and seedling dry weight of *S. coromandelianus*. Lead treatment at 60 ppm significantly reduced shoot, root and and total seedling height of *S. coromandelianus*. Lead treatment at 40 ppm also showed significant decreased on shoot, seedling length and number of leaves of *E. hirta.*

The seedlings of *E. hirta* and *S. coromandelianus* were also used for the development of tolerance indices percentage to different level of lead**.** The seedlings of *E. hirta* and *S. coromandelianus* showed changes in values of tolerance indi**c**es. Lead treatment at 20 ppm showed a positively decreasing influence on the **t**olerance indices of *E. hirta* and *S. coromandelianus*. Increase in **l**ead level a**t** 80 – 100 ppm highly decreased the tolerance indi**c**es percentage of *E. hirta* and *S. coromandelianus* as compared to control. The seedlings of *S. coromandelianus* showed tolerance (68.38%) as compared to *E. hirta* (50.79%) to lead at 100 ppm. The obtained data could be useful for a wide range of researchers working in this aspect.

## 1. Introduction

Pollution by heavy metals (Pb, Cd, Cr, Cu, Fe, Hg, Mn and Ni) in the environment is a nationwide and worldwide pollution problem due to industrial, anthropogenic and automobile activities. Lead is considered as a non essential element for plant growh and human beings. The accumulation of heavy metals in air, water and soil has serious influence on plant growth, vegetation and ecosystem balance. Among the heavy metals, Pb has proved toxic element for biota (Iqbal et al. 2001). There is about 235 million hectares land worldwide has been polluted by heavy metals (Bermudez et al. 2012). Air pollutants likewise lead compounds and heavy metals effects the respiratory, vegetation, photo synthetic pigments, root morphology, enzymatic activities of plants, changes in plant communities (Shahid, et al., 2012; Zeeshan et al. 2016; Gautam et al. 2018; Verma et al. 2021). Effects of chronic stress of lead on anatomical structure of Tobacco roots, and tolerance mechanisms in *Salsola passerina* Bunge and *Chenopodium album* L were recorded (Yuan et al. 2011; Hu et al. 2012). The rsearchers have reported that the excess level lead (Pb) against recommended limit showed harmful effects on seed germination, seedling growth and yield of different plant species due to oxidative damage (Jaja and Odoemena 2004; Prasad et al. 2015; Pietrzykowski et al. 2018; Liu et al. 2020).

The presence of heavy metals in soil also influences on habitant, aquatic life, public health, ecosystem balance and plant growth (Giordani et al. 2005; Yang et al. 2005; Odilara et al. 2006; Joshi et al. 2009; Dribben et

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al. 2011; Shafiq and Iqbal, 2012; Kumari and Deswal, 2017; Gong et al. 2019; Shafiq et al. 2019).

*Species description*

*Euphorbia hirta* Forsk (garden spurge) is a weed, belongs to Euphorbiaceae family and characterized by white milky latex. The morphological, phytochemical, ethnopharmacological, and pharma cological information on *E. hirta* as an herb reviewed on account of medicinal purposes (Kumar et al. 2010). The phytochemistry, pharmacological aspects, toxicological potentials of crude ethanolic extracts of *E. hirta* reported in literature **(**Ogueke et al. 2007; Huang et al. 2012**).**

*Sporobolus coromandelianus* (Retz.) Kunth (true grass) is an annual species of grass and member of Poaceae family (eflora, 2020). *S. coromandelianus* is monocotyledon plan species. *Sporobolus*, Sporo derived from Greek word spora (seed) and bolus (throwing) alluding to the free seed and sometimes forcible manner of its release and common name is small drop seed (AusGrass, 2020). *S. coromandelianus* is a self-sprouting, simple and broad leaves plant species (EOL, 2020). *S. coromandelianus* clumps upto 25 cm tall (Cope, 1999) and its native range is from Eritrea to South Africa, West Indian Oceans, South central China, Jawa, New Guinea, Australia, Namibia, Oman, Sri Lanka, Sudan, Thailand, Yemen, Bangladesh, Afghanistan and native to Pakistan (Kewscience, 2020).

The ever increase of heavy metals in the environment is influencing on the germination and growth of plants. The response of plant growth to abiotic stress has become the subject of great interest in recent years by ecologist. Lead in excess level become toxic element for plants growth. The data on the development of tolerance indices for the native flora in the country is still insufficient. There is dire a need of development of high level of interest in selection of plant species and publication of data on the nature of toxicity and tolerance to metals in plants. Very few studies have been conducted on the effects of lead on the germination and growth of other plants species in Pakistan. The identification of metal tolerant species and plantation in polluted areas might be helpful to lessesn the burden of pollutants from the environment. This study aims to evaluate and compare the effects of lead (Pb) on seedling growth performance of two different plant species, *Euphorbia hirta* Forsk and *Sporobolus coromandelianus* (Retz.) Kunth.

## 2. Materials and Methods

The seedling growth experiment was conducted in green house of the Department of Botany, University of Karachi, Pakistan. Three uniform size seedlings of *E. hirta* and *S. coromandelianus* were collected from the Karahi University campus after moon soon rain fall season in August. The selected two plant species were transplanted in plastic pots (9.0 cm in depth and 7.0 cm in diameter) having garden loam soil. The fraction of soil was one-part manure and two parts of fine sand. There were six metal treatment (0, 20, 40, 60, 80 and 100 ppm) for each plant species and the experiment was completely randomized. The seedlings were irrigated with fresh solutions of 0, 20, 40, 60, 80 and 100 ppm concentration of Pb prepared with lead acetate. Distilled water was applied to control group. 5 ml of respective treatment after the interval of two days was applied. Every week each pot was reshuffled to avoid the effects of shade, light or any other factors of environment. After two months, seedlings were removed from plastic pots and washed with distilled water. The root, shoot, seedling length, number of leaves, leaf area, and root, shoot, leaves and total seedling dry weight were recorded. The root / shoot, leaf weight ratio, specific leaf area and leaf area ratio were recorded (Rehman and Iqbal, 2009). Seedling dry weight was obtained after drying the samples in an oven at 80 °C for 24 hours.

Tolerance indice (T.I.) was determined on the basis of percentage using the following formula given by Iqbal and Rahmati (1992):

T.I. = Mean root length in metal solution Mean root length in distilled water x 100

*Statistical analysis*

Statistical comparisons among all treatments for above and below ground dry plant biomass and proportion contributions thereof to overall dry plant biomass was evaluated using one-way Analysis of Variance (ANOVA) and Steffens post hoc test. Assumption of all tests were tested statistically verified. All statistical analysis was performed using SPSS 10.0 (SPSS) Inc., U.S.A.) for windows.

## 3. Results and Discussion

Despite knowing the phytotoxic effects of heavy metals, which is of global concern, there is a dire need to study about its impacts on native plants. Overall results of different seedlings growth parameters showed that lead is to**xic** element and deleterious for plant growth. The variable responses of a native plant *S. coromandelianus* and *E. hirta* to metal salt likewise lead (Pb) was reorded (Table 1-4; Fig. 1). In the present study the effects of different concentrations 0, 20, 40, 60, 80 and 100 ppm of lead on root, shoot, seedling length, number of leaves, leaf area and seedling dry weights (root, shoot, leaves and total seedling) of *E. hirta* and *S. coromandelianus* were recorded. The lead treatment of 20 ppm showed nonsignificant impact on the root and seedling length of *S. coromandelianus.* The lead treatment of 40 ppm significantly ($p<0.05$) decreased number of leaves and leaf area of *S. coromandelianus*. A rise in concentrations of lead 60 ppm decreased root, shoot, seedling length and biomass production of *S. coromandelianus* as compared control. Lead treatment at 20 ppm indicated toxic effect on shoot, root and seedling height of *S. coromandelianus.* Reduced rate of seed germination and plant growth under stress is mainly due to Pb interference with enzymatic activities seedling dry weights (root, shoot, leaves and total seedling) of *S. coromandelianus* were recorded. Lead treatment at 20 ppm

significantly ($p<0.05$) indicated adverse effect on number of leaves, leaf area, shoot, root, leaf, total plant dry weight, shoot/root, leaf weight ratio, specific leaf area and leaf area ratio of *S. coromandelianus.*

The reduction in root, shoot, seedling length and biomass production of *E. hirta* by concentrations 20, 40, 60, 80 and 100 ppm of lead as compared to control were noted. Air polluion due heavy metals present in soil constitutes negative impacts on tolerance indices of tree (Tripathi et al. 2009). Lead treatment at 20 ppm significantly indicated adverse effect on number of leaves, leaf area, shoot, root, leaf and total plant dry weight of *E. hirta*. A rise in concentrations of lead from 60 to 100 ppm further significantly ($p<0.05$) decreased root and leaf growth of *E. hirta*. Ghani et al. (2010) studied the similar effect of different concentrations (0, 10, 20 and 30 ppm) of lead toxicity on the growth of two varieties of *Zea maize* (Neelam and Desi) in earthen pots. The different response on root / shoot, leaf weight ratio, specific leaf area and leaf area ratio of *E. hirta* to different concentrations 20, 40, 60, 80 and 100 ppm of lead as compared to control were noted.

The application of Pb at 20 ppm promoted shoot and seedling length of *E. hirta*. Maximum suppression of root length (32.30 cm), shoot length (9.50 cm) and seedling length (41.80 cm) of *E. hirta* were obtained at 80 ppm concentration of lead. Maximum suppressed in number of leaves (13.60) and leaf area (7.43) was found with the lead treatment of 100 ppm. Lead treatment at 60 to 80 ppm produced significant ($p<0.05$) decrease on seedling growth performance as compared to control. The shoot (0.28 g), root (0.14 g), leaves (0.046 g) and total plant dry weight (0.466 g) of *E. hirta* seedlings exposed with concentrations of Pb at 100 ppm was recorded. These lead toxicity impact on the growth of *Thespesia populnea* were found similar with the results of Kabir et al. (2008). The results for tolerance indices of *Thespesia populnea* progressively decreased with the increasing concentration of heavy metal. Kabir et al. (2011) reported the different values of tolerance indices of *Samanea saman* for Cu, Fe, Pb and Zn. A high percent of decrease was found in seedling growth and above and belowground biomass of both species with the increase in lead treatment.

The tolerance in seedling growth of *E. hirta* and *S. coromandelianus* differed in their sensitivity to lead treatments in range of 20-100 ppm as compared to control (Fig. 1). The seedlings of both species were found resistant to lead tolerance at 20 ppm concentration as compared to control. An increase in concentration of lead treatment from 40 to 100 ppm increased the toxicity and lower the tolerance indices percentage in seedling growth performance of *S. coromandelianus. S. coromandelianus* showed tolerance indices (68.38%). It was noted that the lead treatment of 80 ppm showed (46.75%) tolerance indices in seedlings of *E. hirta* as compared to control.

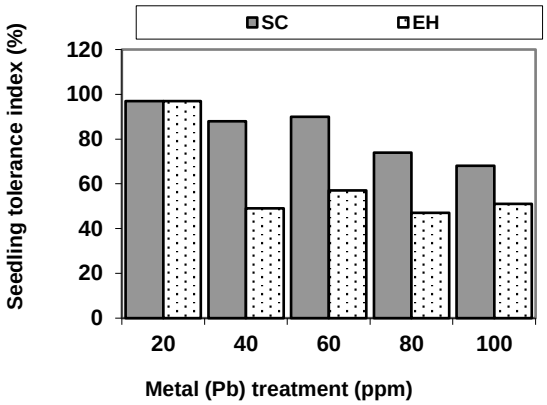


Figure. 1
Seedling tolerance index (%) of SC (*Sporobolus coromandelianus*) and EH (*Euphorbia hirta*) to different concentrations (20, 40, 60, 80 and 100 ppm) of Pb.

Table 1
Effect of lead on seedling growth of *Sporobolus coromandelianus* (Retz.) Kunth and *Euphorbia hirta* Forsk

| Treatment lead (Pb) ppm | Shoot length (cm) | Root length (cm) | Seedling length (cm) | Number of leaf | Leaf area (sq. cm) |
|---|---|---|---|---|---|
| 00 | *49.00±1.08a | 15.50± 0.51a | 64.50±2.07a | 25.10±1.20a | 2.20±0.006a |
| | **36.30±2.15a | 20.30± 0.52a | 56.60±3.14a | 34.50±0.46a | 31.00±0.464a |
| 20 | 44.50±1.07a | 15.00±1.11a | 59.50±2.22a | 25.50±2.23ab | 1.60±0.014ab |
| | 40.16±1.20ab | 19.60±1.08a | 59.76±2.41ab | 33.60±1.74ab | 9.77±0.831ac |
| 40 | 39.70±0.76ab | 13.60±1.45bc 10.00±1.67ab | 53.30±1.57ab | 16.30±0.91b | 2.00±0.02b |
| | 40.60±1.50b | 7.14 ± 0.12a | 50.60±1.46bc | 18.60±4.64b | 5.31±1.04ab |
| 60 | 46.60±3.17b | 14.00±0.72ab | 60.50±3.71b | 14.80±2.21b | 1.03±0.016bc |
| | 36.30±2.36b | 11.50±1.08b | 47.80±3.31a | 22.30±3.97bc | 8.22±0.693b |
| | | 7.14 ± 0.12a | | | |
| 80 | 38.80±1.47bc | 11.60±1.74b | 50.40±2.74bc | 15.30±1.31bc | 0.48±0.005b |
| | 32.30±1.68bc | 9.50±1.84bc | 41.80±2.92b | 22.50±3.12c | 8.05±0.193bc |
| 100 | 37.96±2.29c | 10.60±0.92c | 48.56±2.90bc | 12.00±1.02c | 0.60±0.042c |
| | 34.70±4.70c | 10.30±1.43c | 45.00±5.71c | 13.60±2.27c | 7.43±0.732bc |

Numbers followed by the same letter in the same column are not significantly different according to Duncan Multiple Range Test at $p<0.05$ level.
± Standard Error; **Sporobolus coromandelianus* (Retz.) Kunth, ***Euphorbia hirta* Forsk

Table 2
Effect of lead on dry weight of *Sporobolus coromandelianus* (Retz.) Kunth and *Euphorbia hirta* Forsk

| Treatment lead (Pb) ppm | Shoot dry weight (g) | Root dry weight (g) | Leaf dry weight (g) | Total dry weight (g) |
|---|---|---|---|---|
| 00 | *0.590±0.014a | 0.360±0.002a | 0.060±0.002a | 1.01±0.002a |
| | **0.290±0.01a | 0.200±0.003a | 0.051±0.001ab | 0.541±0.004a |
| 20 | 0.420±0.03ab | 0.185±0.003ab | 0.024±0.002ab | 0.629±0.003ab |
| | 290±0.01ab | 0.116±0.004ab | 0.034±0.001b | 0.440±0.004ab |
| 40 | 0.570±0.03bc | 0.300±0.003b | 0.060±0.002b | 0.930±0.003bc |
| | 0.300±0.02bc | 0.640±0.001b | 0.045±0.002bc | 0.985±0.004b |
| 60 | 0.380±0.03ab | 0.240±0.002ac | 0.040±0.02bc | 0.660±0.004ac |
| | 0.250±0.03bc | 0.098±0.003bc | 0.030±0.001ac | 0.378±0.003bc |
| 80 | 0.520±0.05c | 0.210±0.003b | 0.035±0.002ac | 0.771±0.004bc |
| | 0.240±0.02ac | 0.140±0.003bc | 0.040±0.001bc | 0.371±0.004bc |
| 100 | 0.480±0.03bc | 0.230±0.003bc | 0.060±0.002ab | 0.770±0.003c |
| | 0.280±0.0bc | 0.140±0.003c | 0.046±0.002c | 0.466±0.003c |

Numbers followed by the same letter in the same column are not significantly different according to Duncan Multiple Range Test at p<0.05 level.
± Standard Error;
**Sporobolus coromandelianus* (Retz.) Kunth, ***Euphorbia hirta* Forsk

Table 3
Effect of lead on root/shoot ratio, leaf weight ratio, specific leaf area and leaf area ratio of *Sporobolus coromandelianus* (Retz.) Kunth and *Euphorbia hirta* Forsk

| Treatment lead (Pb) ppm | Root / shoot ratio | Leaf weight ratio | Specific leaf area $cm^{-2}/g$ | Leaf area ratio |
|---|---|---|---|---|
| 00 | *0.610±0.0030a | 0.059±0.760ab | 36.66±2.29a | 2.17±0.158a |
| | **0.680±0.0036a | 0.094±0.003ab | 607.80±1.74a | 57.30±2.29a |
| 20 | 0.440±0.0036ab | 0.038±0.630b | 66.66±0.749ab | 2.54±0.158ab |
| | 0.400±0.01ab | 0.077±0.004b | 287.30±4.64ab | 22.20±0.949ab |
| 40 | 0.526±0.0035ac | 0.064±0.541b | 33.33±2.29b | 2.15±0.152b |
| | 2.13±0.02a | 0.045±0.001bc | 118.00±1.43bc | 5.39±0.158bc |
| 60 | 0.631±0.0037bc | 0.060±0.856ac | 25.75±0.949bc | 1.50±0.891bc |
| | 0.392±0.03ab | 0.079±0.003ac | 276.00±0.52ac | 21.74±3.96ca |
| 80 | 0.399±0.0036c | 0.045±0.145b | 13.71±0.714c | 0.62±0.8564c |
| | 0.379±0.02b | 0.107±0.003c | 201.25±0.001bc | 21.69±3.966b |
| 100 | 0.479±0.0035ac | 0.077±0.098ac | 10.00±0.922ab | 0.77±0.098bc |
| | 0.600±0.0036c | 0.098±0.003c | 161.5246±01.66c | 15.94±0.158c |

Numbers followed by the same letter in the same column are not significantly different according to Duncan Multiple Range Test at p<0.05 level.
± Standard Error;
**Sporobolus coromandelianus* (Retz.) Kunth, ***Euphorbia hirta* Forsk

Table 4
Percentage reduction in shoot length, root length, seedling dry weight and number of leaf of *Sporobolus coromandelianus* (Retz.) Kunth and *Euphorbia hirta* Forsk

| Treatment lead (Pb) ppm | Shoot length (%) | Root length (%) | Total plant dry weight (%) | Number of leaf (%) |
|---|---|---|---|---|
| 20 | *9.10 | 3.20 | 37.70 | $1.50^{+}$ |
| | **$10.60^{+}$ | 3.40 | 2.60 | 18.66 |
| 40 | 18.00 | 12.20 | 7.90 | 35.00 |
| | 11.84 | 50.70 | 46.00 | $82.0^{+}$ |
| 60 | 4.80 | 9.60 | 34.60 | 41.00 |
| | 18.0 | 43.30 | 46.08 | 30.10 |
| 80 | 20.80 | 25.00 | 23.60 | 39.00 |
| | 0.00 | 53.30 | 34.70 | 31.40 |
| 100 | 22.50 | 31.60 | 23.70 | 52.19 |
| | 4.40 | 49.00 | 60.50 | 13.86 |

+ Percentage increase

The harmful effects of lead on seedling growth of *S. coromandelianus* and *E. hirta* was disussed. Seedlings of *S. coromandelianus* exhibited better tolerance to Pb treatments at all treatment as compared to *E. hirta*. The inhibitory impact of lead on seedlings growth were recorded in order *S. coromandelianus*>*E. hirta*. It can be concluded that Pb treatment at higher level produced negative effects on the seedling growth perfomance of both species. Based on toxicity and tolerance indices (%), a great care is required by environmental managers while planting these species in metal contaminated areas.

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# Optimal Sowing Times and Irrigation Schedule of the Chickpea (Cicer Arietinum L.) in Semi-Arid Regions

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**ABSTRACT**

The purpose of this study was to determine the effects of different sowing times and irrigation schedules on seed yield and water use of chickpea in Central Anatolia's semi-arid conditions. For two years, field trials were conducted using a split-block trial design with three replications. The study addressed two sowing times as well as five irrigation treatments. While the effect of sowing time on grain yield varied by year, the effect of irrigation on grain yield was statistically significant for both sowing times. Also, at both sowing times, the three irrigation treatments had the highest grain yield. The efficiency of the water use was higher in late sowing than in early sowing. While plant water consumption increased during the early sowing period, the amount of irrigation water decreased. The seasonal yield response factor in early sowing, on the other hand, was lower than in late sowing.

## 1. Introduction

Chickpea is the third most-produced legume after cereals in the world in terms of cultivation area and production amount. Chickpeas, which are an important source of vegetable protein, have an important place in human nutrition, especially in countries where animal protein sources are insufficient. World chickpea production is mostly grown in South and West Asia, the Middle East and Southeast regions of Asia, North Africa, North, and Central America, and Europe. Approximately 80-85% of chickpeas produced have been producing by only four countries, India, Turkey, Pakistan, and Iran. In the world, from 14.8 million hectares of land cultivated, 14.24 million tons of products were obtained, and an average yield is 960 kg $ha^{-1}$ (FAO-STAT, 2015).

Chickpea is one of the most grown plants after beans and lentils. Chickpea, which is the most drought and temperature resistant plant after lentils, is one of the most important plants in semi-arid and arid areas. It is the most important alternative plant to be used in the evaluation of light-textured soils in arid regions. For this reason, Chickpea has been included in the planting pattern of the southeastern and central regions of Anatolia.

Chickpea cultivation area in Turkey is 520,000 hectares, while the total production is 620,000 tons, while the yield per hectare is around 1.2 tons (TURKSTAT, 2018). In recent years, chickpea production has decreased in parallel with the chickpea cultivation areas. On the other hand, the spread of anthracnose during rainy periods has a decreasing effect on production. That's why, it was aimed to prevent the spread of anthracnose by delaying the sowing times as well as chemical control.

Many studies have been conducted to determine the effect of irrigation schedule and planting times on chickpea yield. According to Güngör (1980), it should be irrigated at thirty percent of the effective moisture in the effective root zone. According to Günbatılı (1986), two irrigations are sufficient.

Winter sowing in Sicily increased chickpea seed yield by 21% (Calcagno et al., 1987). While early sowing increases chickpea yield by 65%; irrigation increased by 73% the yield (Saxena et al., 1990), late sowing negatively affected plant height and seed size (Poma et al., 1990). Adequate soil moisture is a requirement for an optimum plant number, good growth, and high yield (Singh et al., 2011). Many researchers have observed that optimum humidity conditions during the pod set binding period increase the transfer of assimilates to the reproductive organs, thus reducing flower and increasing yield (Leport et al., 1998, 2006). Water stress causes reproductive development to cease while the plant enters the reproductive stage and consequently the yield decreases. Turner et al., (2006) reported that irrigation during pod development caused an increase in the number

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of pods per plant by delaying the cessation of flowering and pod set development (Leport et al., 1999, 2006).

Many studies have shown that one irrigation (Munirathnam and Sangita, 2009), two irrigations (Abraham et al., 2010), or three irrigation applications (Mansur et al., 2010) significantly increase chickpea grain yield. However, the actual number of irrigations required depends on many factors such as the amount of precipitation received, soil structure, weather conditions, and growing period. Singh et al. (2015) reported that 75 mm of water in vegetative and vegetative + pod formation stages provided a 59% and 73% increase in seed yield, respectively.

Chickpea cultivation in semi-arid climate zones is generally based on rainfall due to the insufficient water resources of these regions. However, considering the growth periods of the plant during the growing season, it has been discussed to what extent one or two irrigations will affect the yield levels in chickpeas. This study mainly deals with the effects of irrigation schedules created for early and late sowing and different growth periods on chickpea yield and water consumption.

## 2. Material and Method

Field trials were conducted in Central Anatolia on the Konya Plain. The trial site has a height of 1016 m and is located at $37^0$ N and $32^o$ E longitude.


Figure 1
The geographic location of trial site

The soil at the trial site is clayey, sandy, and very calcareous. Its organic matter content is low, and its sand content is high. There was no salinity problem in soils with a slightly alkaline reaction. Considering the soil properties related to irrigation, the field capacity at 60 cm depth was 289 mm and favorable humidity was 158 mm (Table 1).

The area where the trial was conducted has a semi-arid climate with an average annual precipitation of 316 mm, 9% of which falls in the summer. The other seasons receive almost equal amounts of rainfall. It is 36%, 24%, and 31% in spring, autumn, and winter, respectively. The weather is hot and dry in the summer, and cold and snowy in winter.

The weather data for the growing season are presented in Table 2. The average total precipitation from October to harvest varies between and 110-130 mm for the growing season.

In the trial, the Seydişehir chickpea (Cicer arietinum L.) variety was used. Recommended for Central Anatolia, this variety is a mid-late variety, ram-shaped, sensitive to anthracnose, medium-sized, high-yielding, 2.50-3.50 t $ha^{-1}$ in irrigated conditions, and 1.0-2.0 t $ha^{-1}$ in rain-fed agriculture (Kayıtmazbatır, 1978).

The experiments were arranged as A- two sowing times and B–five irrigation schedules, and the field trials were carried out for two years with three replications in the split block trial design.

A-Sowing times

$E_1$: Early sowing, the second half of March, $E_2$: late sowing, and the first half of May.

B-Irrigations considering the phenological development periods of chickpeas

$I_0$: Based on rainfall, $I_1$: 5% flowering, 1 water, $I_2$: 1 irrigation for 5% +, $I_3$: $I_1 + I_2$, two irrigations, $I_4$: $I_1 + I_2$ + pod filling.

After the wheat harvest, the field was ploughed and left for winter. In early spring, after the second ploughing of a disc harrow, it was prepared for sowing by fine levelling.

Plant row spacing is 0.35 m and row top is 0.10-0.15 m, sowing depth is 4-5 cm. Each trial plot has a total area of 7.0 m x 3.15 m = 22.05 $m^2$ in sowing, and 6.0 m x 1.75 m (10.50 $m^2$) in the harvest. A sufficient distance is left between the parcels and blocks to prevent horizontal water flow. The experiments were performed using a three-replicated split block trial design. Sowing times are the main treatments and irrigations are a sub-treatment.

The same amount of fertilizer (60 kg $ha^{-1}$ $P_2O_5$ and 30 kg $ha^{-1}$ N) was applied to all trial plots.

Irrigation water was calculated by determining the current moisture, and the moisture deficit was calculated to match the field capacity. While calculating the irrigation water requirements, the moisture consumed in the 60 cm soil profile was taken into account. Soil moisture was measured gravimetrically before irrigation and at the beginning of each growth period, and the amount of irrigation water to be applied afterward was calculated using the following equation:

$$IW = 1000\,(A)\,(\Delta SW)\,(A_s)\,(D_{rz}) \qquad (1)$$

where IW is the amount of irrigation water, A is the parcel area $m^2$, ΔSW is the soil water deficit at root depth before irrigation, g $g^{-1}$; is the difference between field capacity and soil water content; volume weight of soil, g $cm^{-3}$; and $D_{rz}$ is the soil depth or effective root zone, m. The calculated amounts of irrigation water were applied through the flowmeters.

When the plants were 10 cm tall, the first hoe, light throat filling, and weed removal were performed before blooming.

The seeds were sprayed against fungal diseases such as anthracnose.

Harvesting and threshing were done by hand when the plants reached harvest maturity.

Table 1
Some soil properties of the trial site

| Soil depth (cm) | pH | ECe (dS $m^{-1}$) | Bulk density (g $cm^{-3}$) | Field capacity (g $g^{-1}$) | Wilting point (g g-1) | Lime % |
|---|---|---|---|---|---|---|
| 0-30 | 8.1 | 0.56 | 1.53 | 29.43 | 11.05 | 22 |
| 30-60 | 8.1 | 0.60 | 1.65 | 31.13 | 16.17 | 23 |
| 60-90 | 8.1 | 0.48 | 1.56 | 32.59 | 17.73 | 25 |

Statistical analysis and evaluations were made according to Yurtsever (1984).

Water consumption was calculated using the following water balance equation (James, 1988).

$ET = IW + P + C_p + D_p \pm R_{off} \pm \Delta S$ (2)

ET, evapotranspiration (mm); IW, amount of irrigation water; P precipitation amount; Roff, surface flow; Dpis deep percolation; $C_p$, capillary rise, and ΔS are the changes in moisture content at soil depth (units are mm). In the ET calculations, $R_{off}$, $D_p$, and $C_p$ are taken as zero-because there is no surface flow, deep percolation, or capillary rise.

Water use efficiency was determined using the equations given by Howell et al. (1994).

$IWUE = (Y-Y_0) / I$ (3)

$WUE = Y / ET$ (4)

IWUE and WUE: kg $m^{-3}$, I, applied irrigation water, mm; Y is marketable chickpea yield, kg $da^{-1}$, $Y_0$, yield under non-irrigation conditions, kg $da^{-1}$, ET, seasonal (total) evapotranspiration, mm

Table 2
Long-term climate data for the trial site

| | Months | | | | | | | | | | | | Total/average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | X | XI | XII | I | II | III | IV | V | VI | VII | VIII | IX | |
| Precipitation, mm | 36 | 32 | 34 | 38 | 26 | 26 | 41 | 46 | 21 | 5 | 4 | 7 | 316 |
| Mean temp., C° | 11 | 4.8 | 0.5 | -1.5 | 0.5 | 5 | 10.6 | 15 | 19.2 | 22.3 | 21.3 | 17.3 | 10.5 |
| Evaporation, mm | 90 | 23 | - | - | - | - | 110 | 147 | 196 | 254 | 231 | 163 | 1213 |
| Rel. Humidity, % | 62 | 72 | 78 | 77 | 72 | 65 | 59 | 57 | 51 | 45 | 46 | 50 | 51 |
| Wind speed, m $s^{-1}$ | 1.8 | 2.1 | 2.2 | 2.4 | 2.7 | 2.9 | 3 | 2.5 | 2.5 | 2.8 | 2.4 | 1.9 | 2.4 |

## 3. Results and Discussion

Depending on the weather conditions during the growing period, early sowing resulted in a longer growth period and late sowing resulted in a shorter growth period. The development period of late sowings was shorter by 5 days in the first year and 15 days in the second year (Table 3).

Table 3
Chickpea development periods in early sowing

| Observations | Early sowing | | Late sowing | |
|---|---|---|---|---|
| | 1. yr | 2. yr | 1.yr | 2.yr |
| Sowing date | 28.3 | 30.3 | 8.5 | 7.5 |
| Germination | 17.4l | 18.4 | 29.5 | 17.5 |
| Flowering | 1.6 | 12.6 | 30.6 | 25.6 |
| Pod-set | 22.6 | 29.6 | 18.7 | 12.7 |
| Pod-filling | 4.7 | 14.7y | 30.7 | 28.7 |
| Harvest | 23.7 | 10.8 | 28.8 | 1.9 |
| Growth period days | 117 | 132 | 112 | 117 |

An average yield of 980 kg $ha^{-1}$ was obtained from early sown and non-irrigated ($I_0$) plots and 890 kg $ha^{-1}$ from late sowing. Before flowering, pod formation, and pod filling, from three irrigated ($I_4$) and early sown treatments, an average of 2030 kg $ha^{-1}$ and seed yield of 2760 kg $ha^{-1}$ were obtained from those sown late. Grain yields obtained from other treatments were among these values (Table 4).

Ugale et al., (2000) that the lowest average yield was obtained at 1.110 t $ha^{-1}$ when chickpeas are not irrigated, Pramanik et al. (2009), on the other hand, irrigation during the branching and pod period increases the grain yield significantly (2.24 t $ha^{-1}$), Lende and Patil (2017) reported that seed yield increased significantly (2.692 t $ha^{-1}$) with six irrigations during the branching and pod-set development phase.

Table 4
Chickpea grain yields (t $ha^{-1}$) according to treatments

| Treatments | Early sowing (ES) | | | Late sowing, (LS) | | |
|---|---|---|---|---|---|---|
| | 1.yr | 2.yr | Average | 1.yr | 2. yr | Average |
| $I_0$ | 0.93 | 1.03 | 0.98 | 0.83 | 0.95 | 0.89 |
| $I_1$ | 1.49 | 1.32 | 1.41 | 1.26 | 2.34 | 1.80 |
| $I_2$ | 1.11 | 1.74 | 1.43 | 1.13 | 2.23 | 1.68 |
| $I_3$ | 1.69 | 1.75 | 1.72 | 2.01 | 2.98 | 2.50 |
| $I_4$ | 2.10 | 1.97 | 2.03 | 2.03 | 3.49 | 2.76 |

The effect of sowing time on chickpea yield was insignificant in the first year, while the second year was significant at the level of 0.01 ($F_{calc}$ = 399.62**>($F_{0.01}$ = 98.50), and the interaction between sowing times and irrigation in the first year was found to be statistically significant ($F_{calc}$)=12.56*> (F0.05 = 3.84).

This study showed that irrigation significantly increased the chickpea yield in semiarid regions. Irrigation during flowering, pod formation, and pod-set filling yielded similar results for both sowing times. According to the results of variance analysis, the effect of irrigation treatments on chickpea yield in both years was found to be statistically significant (0.01) ($F_{calc}$ = 66.99** 1.yr 80.87** and 2. yr, $F_{0.01}$=7.01).

According to Duncan test results, $I_4$ treatments irrigated three times in all years constituted the first group for both sowing times. $I_4$ treatments were followed by $I_3$, which were watered twice. While $I_1$ and $I_2$, once irrigated, did not provide a significant advantage to each other, $I_0$ treatments alone constituted the last group and early sown $I_0$ outperformed late-sown $I_0$ treatments (Table 5).

Irrigation provided a significant yield increase for both planting times, depending on the rainfall. For example, one irrigation applied before flowering or pod formation, in early sown plots increased the seed yield

by 30 %–31% on average, while pre-flowering one irrigation increased by 51%–47% in late sowing. Two irrigation yields increased by 43% in early sowing and 64% in late sowing (Table 6). On the other hand, three irrigation yields were increased by 52% in the early sowing period, and 68% in the late sowing period. As can be seen, the effect of irrigation on yield increase in late sowings was greater than that sown early.

Table 5
Duncan ranking of the treatments according to their grain yields

| Treatments | Early sowing (ES) | | Late sowing (LS) | |
|---|---|---|---|---|
| | 1. yr | 2. yr | 1. yr | 2. yr |
| $I_0$ | 0.93e | 1.03ef | 0.83f | 0.95f |
| $I_1$ | 1.49bc | 1.32e | 1.26cd | 2.34c |
| $I_2$ | 1.11de | 1.74d | 1.13de | 2.23c |
| $I_3$ | 1.69b | 1.75d | 2.01a | 2.98b |
| $I_4$ | 2.10a | 1.97a | 2.03a | 3.49a |

(p=0.05)

Many researchers have similarly reported that irrigation for late sowing causes higher increases in seed yield than early sowing. Bray (2002) stated that soil moisture deficit is more important than crop growth periods in planning irrigation.

The researcher pointed out that increasing low temperatures during early flowering appears to be the result of flower fall and watering, so the timing of single irrigation may depend on the region's weather conditions and the weather conditions of the particular season.

Table 6
Increase rates in chickpea grain yields

| Treatments | Early sowing (ES) | | | Late sowing, (LS) | | |
|---|---|---|---|---|---|---|
| | 1.year | 2.year | Average | 1.year | 2. year | Average |
| $I_1$ | 0.38 | 0.22 | 0.30 | 0.35 | 0.59 | 0.51 |
| $I_2$ | 0.16 | 0.41 | 0.31 | 0.26 | 0.57 | 0.47 |
| $I_3$ | 0.45 | 0.41 | 0.43 | 0.59 | 0.68 | 0.64 |
| $I_4$ | 0.56 | 0.48 | 0.52 | 0.59 | 0.73 | 0.68 |

The increase in the number of irrigation and water consumption in chickpeas significantly increased the grain yield.

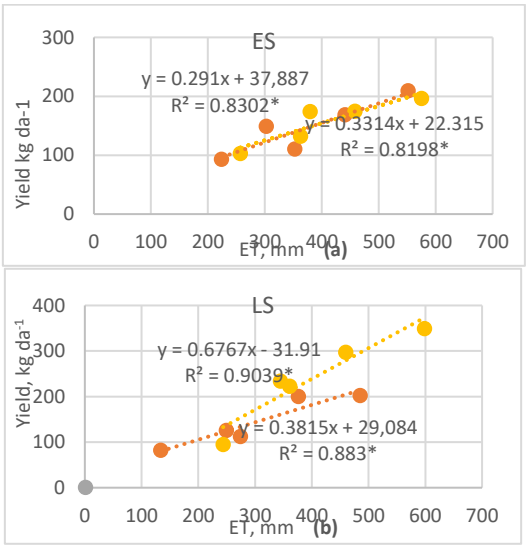


Figure 2
ET and grain yield relationships at different sowing.

High correlation coefficients of both early sowing and late sowing ($1_{st}$yr, $R^2$ = 0.82-0.83, and $2^{nd}$yr, $R^2$=0.90-0.88) were found to have linear relationships between ET and seed yield (Figures, 2a, 2b).

An average of 100 mm in early sowing fields ($I_1$) and early sown fields before flowering, 115 mm in late-sown fields, 333 mm in three irrigated ($I_4$), and early sown plots; 357 mm of irrigation water was applied to those sown late. The amount of irrigation water supplied to the other treatments varied between these values.

The ET values increased in proportion to the amount of irrigation water applied.

Table 7
Amounts of irrigation water applied to treatments (mm)

| Treatments | Early sowing (ES) | | | Late sowing, (LS) | | |
|---|---|---|---|---|---|---|
| | 1.yr | 2.yr | Average | 1.yr | 2. yr | Average |
| $I_0$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $I_1$ | 95 | 105 | 100 | 121 | 109 | 115 |
| $I_2$ | 137 | 118 | 127 | 143 | 125 | 134 |
| $I_3$ | 213 | 202 | 208 | 246 | 224 | 235 |
| $I_4$ | 347 | 319 | 333 | 366 | 349 | 357 |

In both sowing periods, the first-year ET values were found to be lower than the second-year ET values (Table 8, Figure 2a). In contrast, while the Meat values of the early sown treatments were significantly higher (p=0.0004), the differences in ET values were found to be insignificant in the second year (p = 0.565).

Table 8
Sowing times and seasonal ET values, mm

| Treatments | Early sowing (ES) | | | Late sowing, (LS) | | |
|---|---|---|---|---|---|---|
| | 1.yr | 2.yr | Average | 1.yr | 2. yr | Average |
| $I_0$ | 224 | 257 | 241 | 134 | 244 | 189 |
| $I_1$ | 303 | 363 | 332 | 250 | 345 | 297 |
| $I_2$ | 353 | 380 | 366 | 274 | 361 | 317 |
| $I_3$ | 441 | 458 | 449 | 376 | 460 | 418 |
| $I_4$ | 552 | 575 | 564 | 485 | 599 | 542 |

(p=0.002)

When the two-year mean values were taken into account, the ET values of the early sowing treatments were found to be significantly higher than those sown late (p=0.002). The long growing period of the early sown chickpea plants caused an increase in ET values (Figure 3a, 3b). Lende and Patil (2017) reported that the highest water saving was observed when irrigation was applied in branching and pod development.

In the first year, irrigation water use efficiency (IWUE) ranged from 0.13 to 0.59 kg $m^{-3}$ for early sown crops and from 0.21 to 0.48 kg $m^{-3}$ for late sown crops. In the second year, however, IWUE ranges between 0.28 and 0.61 kg $m^{-3}$ in early-sown crops and 0.73 and 1.27 kg $m^{-3}$ in late-sown crops. Sowing times had a statistically significant effect on IWUE based on average values. (p=0.014) (Table 9 ve Figure 4a).

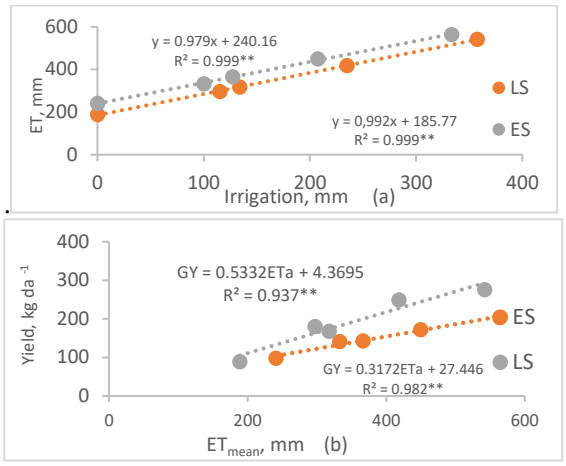


Figure 3
Relationships between mean seasonal ET vs. mean grain yield (GY)

Water use efficiency (WUE) ranged from 0.38 to 0.49 kg $m^{-3}$ for early sown crops and from 0.41 to 0.62 kg $m^{-3}$ for late sown crops in the first year. In the second year, WUE ranges between 0.34 and 0.46 kg $m^{-3}$ in early-sown crops and 0.39 and 0.68 kg $m^{-3}$ in late-sown crops. Based on average values, sowing times had a statistically significant effect on WUE. (p=0.004), (Table 9 and Figure 4b).

Oweis et al. (2004) stated that water use efficiency is significantly affected by planting time, irrigation and their interactions, Pramanik et al. (2009) found the water use efficiency of chickpea to be 1,169 kg $m^{-3}$

One unit of decrease in proportional water consumption in Konya conditions caused 0.85 units of decrease in yield in early sowing and 0.91 decreases in late sowing (Figure 4).

Table 9
Average irrigation water use efficiency of treatments

| Treatments | Early sowing (ES) | | | Late sowing, (LS) | | |
|---|---|---|---|---|---|---|
| | 1.yr | 2.yr | Average | 1.yr | 2. yr | Average |
| I1 | 0.59 | 0.28 | 0.45 | 0.36 | 1.27 | 0.95 |
| I2 | 0.13 | 0.61 | 0.40 | 0.21 | 1.02 | 0.64 |
| I3 | 0.35 | 0.36 | 0.39 | 0.48 | 0.91 | 0.80 |
| I4 | 0.33 | 0.29 | 0.36 | 0.33 | 0.73 | 0.59 |

*(p=0.014)*

Zhang et al. (2000) reported that the average WUE values of chickpeas grown in the Mediterranean environment were 0.32 kg $m^{-3}$. Lende and Patil (2017) reported that the highest water use efficiency was achieved by irrigating all furrows at the pod filling stage (as 1.03kg $m^{-3}$).

Table 10
Average water use efficiencies of trial treatments (kg $m^{-3}$)

| Treatments | Early sowing (ES) | | | Late sowing, (LS) | | |
|---|---|---|---|---|---|---|
| | 1.yr | 2.yr | Average | 1.yr | 2. yr | Average |
| I0 | 0.42 | 0.40 | 0.41 | 0.62 | 0.39 | 0.47 |
| I1 | 0.49 | 0.36 | 0.42 | 0.51 | 0.68 | 0.61 |
| I2 | 0.31 | 0.46 | 0.39 | 0.41 | 0.62 | 0.53 |
| I3 | 0.38 | 0.38 | 0.38 | 0.53 | 0.65 | 0.60 |
| I4 | 0.38 | 0.34 | 0.36 | 0.42 | 0.58 | 0.51 |

Single irrigation with early sowing (early and mid-February) increased the average yield by 65% and WUE value by 51% (Amiri et al., 2016). As a result, early sowing has been increasing WUE compared with late sowing according to regions and irrigation regimes.

The yield response factor (ky), which expresses the relationship between the proportional yield decrease and the proportional evapotranspiration decrease was determined as 0.85 for early sowing and 0.91 for late sowing, respectively.

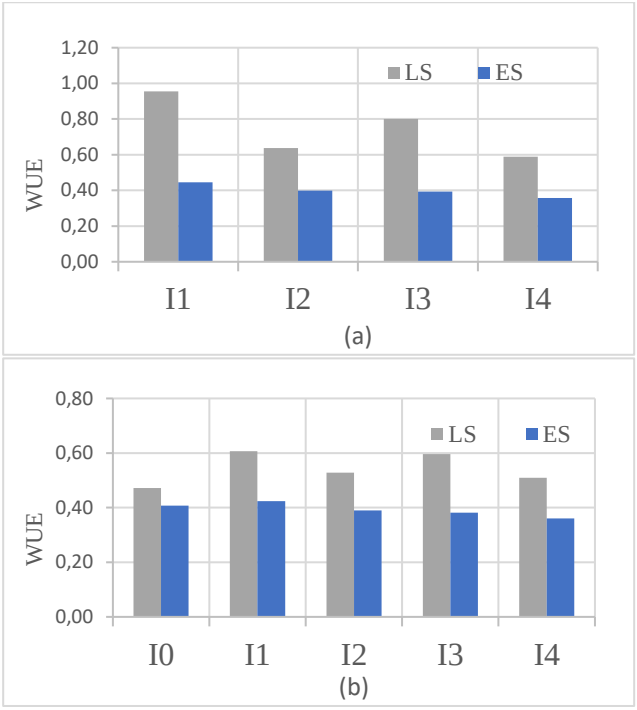


Figure4
Average WUE and IWUE values determined vs different sowing time and irrigation schedules of chickpea

These results show that chickpeas are relatively insensitive to water stress. Seasonal water shortages have been found to affect chickpea yield more in late sowing. It has been reported that the yield response factor for chickpea (ky) under Çukurova conditions is 1.06 (Yılmaz, 2011), and in northwest India between 0.67 and 0.93 (Jalota et al., 2006). It can be said that the data obtained in this study are compatible with similar study results.

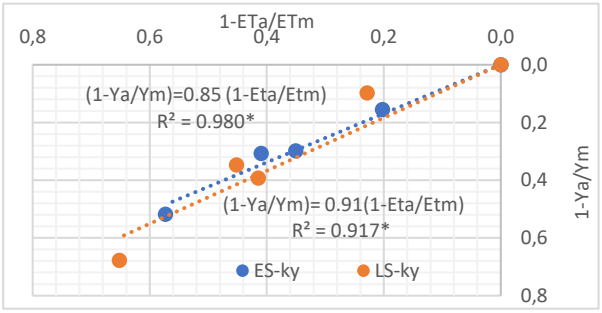


Figure 5
Relations between proportional ET reduction and proportional yield decrease in chickpea plant at different sowing times.

## 4. Conclusion

Chickpeas, which are sown early in the semi-arid conditions of Central Anatolia, prolonged the growth period by approximately 1-2 weeks. While sowing time did not affect seed yield in irrigated fields, early sowing significantly affected seed yield in non-irrigated fields. The reason for this is that chickpeas sown early have more opportunities to benefit from winter and spring rainfall.

Early sowing caused an increase in water consumption, whereas late sowing caused an increase in irrigation water. Although early sowing increased the risk of anthracnose, it was not observed during the two-year trial. It has been observed that fungal diseases such as anthracnose can be prevented by appropriate agricultural control. If single irrigation is performed in case of water shortage, it should be preferred to irrigate before flowering because the water need is less. However, monitoring soil moisture changes is necessary for optimum water management and yields.

Water resources in Central Anatolia are insufficient to irrigate many crops. As a result, plants whose growth period coincides with the hot and dry summer season suffer significant yield loss due to a lack of water. As a result, in terms of water management, it is critical to implement agricultural practices that maximize the use of winter precipitation while also expanding crop cultivation based on early spring precipitation and moisture accumulated in the soil. However, in order to prevent damage due to anthracnose and fungal diseases, chemical treatments should not be ignored as well as resistant varieties.

## 5. Acknowledgements

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**Research Article**

# Defining and Predicting Consumers' Bread Choices based on Socio-Demographic Characteristics and Healthy Living Orientations

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**ABSTRACT**

The bread still constitutes an essential part of meeting the daily nutritional requirement. This study, it is tried to define and predict the behavioral attitudes of consumers toward bread consumption. The primary purpose of this study is to examine the socio-demographic characteristics of individuals and their bread consumption preferences and perceptions with a focus on quality and healthy life. The data are obtained digitally with 9583 consumers from survey questions created on google form throughout Turkey throughout the year 2020. First, descriptive statistics of the answers to the comprehensive survey questions are revealed. Then, correlation analysis was conducted to show the relationships between the variables, in line with each sub-objective set up under the primary purpose. Finally, by using some data mining and machine learning algorithms, it is tried to reveal future expectations based on some main determinant parameters such as health and quality expectation for bread consumption of consumers. All statistical and inferential evaluations were made using the Konstanz Information Miner (KNIME) analytics platform. The findings discover that increasing income and education level in bread consumption improves the level of awareness about health and quality of life in people, and these attitudes and perceptions bring about a proportional decrease in bread consumption of individuals. On the other hand, as a vicious circle, it reveals that the sedentary life brought by work-life in modern society causes an increase in body weight and an unhealthy living ecosystem. The findings can offer meaningful advice to all actors and political decision-makers involved in the bread market and supply chain and consumers.

## 1. Introduction

Bread is a historical and traditional food that has been proven to be used more than 5000 years ago in Mesopotamia and Ancient Egypt (De Boni et al., 2019). Today, with the increase in population, bread consumption also shows steady growth. On the other hand, it is seen that there has been a significant decrease in bread consumption in recent years, especially in developed countries (Eglite and Kunkulberga, 2017). While the average per capita bread consumption is 70 kg globally, this amount is 59 kg in European countries. While the lowest levels are in question in Great Britain and Italy with approximately 31 kg, the consumption of bread per capita is 95 kg in Bulgaria and 104 kg in Turkey (Eglite and Kunkulberga, 2017; De Boni et al., 2019). While bread consumption per capita is only 10 kg in African countries, it is 118 kg in Middle Eastern countries (Cagri, 2016).

In addition to the socio-demographic characteristics and consumption habits of the consumers, the product characteristics and variety, the type of grain from which it is obtained, the product processing and production system, the possible effects of bread on human health are very important (Sandvik et al., 2014; Sajdakowska et al., 2019).

The share of bread (about 11%) in consumers' food and beverage expenditures is still significant (WB, 2019). However, almost half of the daily average calorie need of Turkish people is still met by bread. Turkey entered the Guinness World Records with the title of "highest bread consumption per capita" in 2000 (GWR, 2020). Due to the reasons that are tried to be explained, it is observed that bread is one of the most popular food

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products in Turkey. On the other hand, it has been established by most of society, not only as a beloved product but also as an essential sacred value (Sarica et al., 2021).

This study tried to define and predict the behavioral attitudes of consumers toward bread consumption. Therefore, consumers' most distinctive socio-demographic characteristics and the most specific attitudes and behaviors related to bread consumption are selected. To achieve as clear results as possible, descriptive statistics such as arithmetic mean and standard deviation and classical statistical methods such as correlation analysis are used. In addition, one of the crucial facts that make the study superior is the use of decision trees and naive Bayes algorithms, which are data mining methods. Thus, a more straightforward definition and estimation are possible.

After the introduction section, the methodology used is represented. In the following stage, descriptive statistics of the variables, correlation analyses, and the results of various machine learning algorithms are presented. In each process, the nodes used in the Konstanz Information Miner (KNIME) (2021) are first introduced, and then the main findings are presented. Finally, the conclusion is presented. Therefore, as far as we know, this research is the first to examine the socio-demographic characteristics of the individual and their bread consumption preferences and perceptions using this method.

## 2. Materials and Methods

*Sample and Data Collection Process*

The data are obtained in the digital environment with 9583 consumers from survey questions created on google form throughout Turkey throughout the year 2020. A survey was conducted with 9583 consumers in 81 provinces, and most consumers are concentrated in Aydın, Antalya, Hatay, Muğla, Kocaeli, Mersin, Eskişehir, Van, Tekirdağ, Gaziantep (Figure 1).

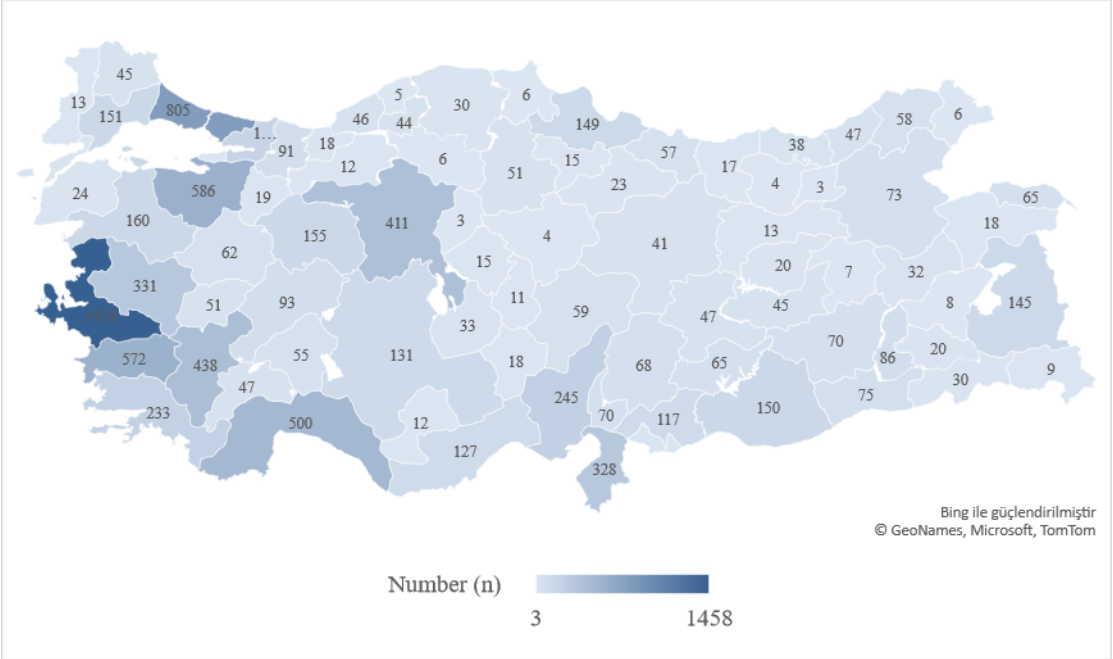



Figure 1
Research provinces in Turkey

*Description of Questionnaire*

The subjects covered in the study are built on certain main bodies, and the questions in the survey study are formed within this framework.

(1) Some personal and socio-demographic characteristics of the participants.

(i) Age (kg)

(ii) Gender (1 = male, 0 = female)

(iii) Marital status (1 = married, 0 = otherwise)

(iv) Height (cm)

(v) Body weight (kg)

(vi) Education (0 = illiterate, 1 = primary education, 2 = high school, 3 = Bachelor's degree, 4 = postgraduate)

(vii) Working status (1 = yes, 0 = otherwise)

(viii) a question: Do you have a disease diagnosed by a doctor? (1 = yes, 0 = otherwise)

(ix) a question: Do you exercise regularly? (1 = yes, 0 = otherwise)

(x) Income rate (₺/month) (1 = up to 750, 2 = 751-1500, 3 = 1501-3000, 4 = 3001-5000, 5 = 5001-10000, 6: over 10000) [Note: According to the data of the Organization for Economic Cooperation and Development (OECD), 1 $ has been calculated as approximately 7 ₺ in 2020 (OECD, 2021)].

(2) Various characteristics, perceptions, and attitudes of consumers regarding their bread consumption preferences.

(i) a question: Do you think bread is a portion of healthy food? (1: yes, 0: otherwise)

(ii) a question: Which of the following types of bread do you think is the healthiest? (1: yes, 0: otherwise)

- Grain bread (mixed, grain, wholewheat, rye, oat, corn)
- White bread, pita, lavash (wheat flour)
- Sourdough, dough bread (wheat, wholewheat, grain)
- Wholewheat bread, pita, lavash (wholewheat flour)

(iii) a question: Why do you think additives are used in bread making? (1: yes, 0: otherwise)

- Increase the durability of bread
- Increasing the nutritional value
- To give aroma and flavor
- Correcting and improving the appearance
- Delay staling

(iv) a question: What kind of health effects do you think the additives used in bread making have? (1: yes, 0: otherwise)

- Causes allergies
- Causes obesity
- Causes other health problems
- Causes an increase in cholesterol
- Does not cause health problems

(v) a question: How do you know when the bread is stale (too much to be consumed)? (1: yes, 0: otherwise)

- If the bread is crumbly
- If the bread is moldy
- If the bread is hard
- If the bread is hard and crumbles easily
- If the appearance of the bread is distorted
- If the appearance of the bread has changed
- If it is not consumed on the day, it is taken
- If the smell of the bread has changed
- If the taste of the bread has changed

(vi) Attitudes, ideas between bread, and some health-related features. (1 = I totally disagree and 5 = I totally agree)

- Wholewheat bread should be preferred instead of white bread to reduce the risk of obesity, heart, and chronic diseases
- Bread strengthens the immune system
- Bread regulates the digestive system
- Wholewheat bread is healthier
- White bread is unhealthy
- Eating bread makes you gain weight
- Overeating bread makes you gain weight
- Bread is a source of energy
- Consuming bread keeps you full
- Additives used in bread making are harmful to our health

(vii) a question: Where do you often buy your bread? (1: yes, 0: otherwise)

- Bakery
- Grocer
- Buffet
- I do it myself at home
- Municipal outlet
- Market

(viii) a question: Which type of bread do you often consume? (1: yes, 0: otherwise)

- White bread
- Pita
- Lavash (with wheat flour)
- Sourdough/dough bread (wheat, wholewheat grain)
- Grain bread (mixed grain, wholewheat, rye, oat, corn)
- Wholewheat bread

(ix) a question: What are the points you pay attention to when buying bread? (1: yes, 0: otherwise)

- Being close to reach
- Size
- Packaging
- Company name
- View of bread
- Producing quality bread
- Sellers are smiling
- Additive in bread
- The calorie level of bread
- Easy to find
- To be salt-free
- Being hot and fresh
- To be well cooked
- Being cooked in a wood oven
- Produced/sold in a hygienic environment

(x) a question: What do you think about the quality of the bread you consume? (1: very bad, 2: bad, 3: average, 4: good, 5: very good)

(xi) a question: What are the reasons why you do not find the quality of the bread satisfactory? (1: yes, 0: otherwise)

- The manufacturer's disregard for quality
- Uneducated bakers
- Presence of excessive and unconscious additives in bread
- Bread not cooked well
- Bakers not paying attention to cleanliness

- Poor quality of flour used in bread production
- Using bleach in bread making
- Bread is tasteless

(xii) a question: How many slices of bread do you eat per day? (No = 0, 1 = one or two slices in a day, 2 = three to four slices in a day, 3 = five to six slices in a day, 4 = more than six slices in a day)

(xiii) a question: Do you eat bread with meals? (1: yes, 0: otherwise)

(xiv) a question: Which food or meal would you like to consume bread with? (1: yes, 0: otherwise)

- Soup
- Slops
- Meat, chicken, and rice
- Rice and pasta
- I never consume

(xv) a question: In which meals do you mostly consume bread? (1: yes, 0: otherwise)

- At breakfast
- At lunch
- At snacks
- At the dinner

(xvi) a question: How do you determine the staling of bread? (1: yes, 0: otherwise)

- Bread hardening and crumbling
- Changing the taste of bread
- Bread molding
- If not consumed that day
- If the appearance of the bread has changed

(xvii) a question: How do you evaluate stale bread? (1: yes, 0: otherwise)

- I make breadcrumbs, crusty bread, etc.
- I use it dry
- I feed the animals
- I use it as a meatball paste
- I give the bread to the milkman and the porter
- I do not evaluate it in any way. I throw it away
- I use it in soup and food
- I give to what is needed

(xviii) a question: How do you store the bread? (1: yes, 0: otherwise)

- I keep it in the freezer
- I consume it by heating
- I keep it in the fridge

## 3. Results and Discussion

*Descriptive Statistics of the Variables*

First, descriptive statistics of the variables used in the study are presented (Table 1). Then, the workflow used for this is stated below (Figure 2).

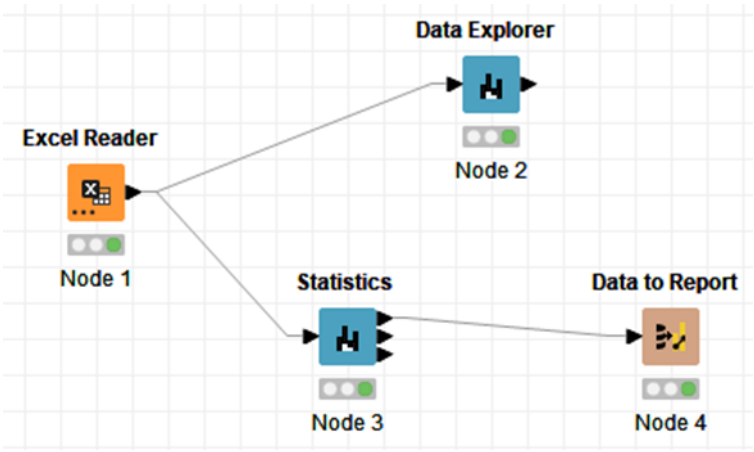



Figure 2
KNIME workflow for descriptive statistics

Table 1
Descriptive statistics of the variables/statements

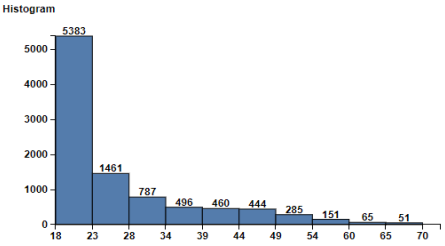
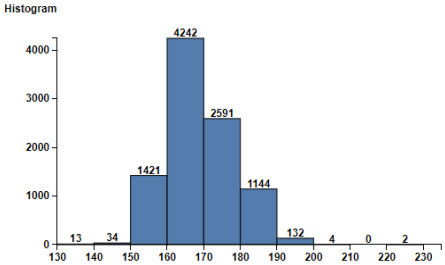
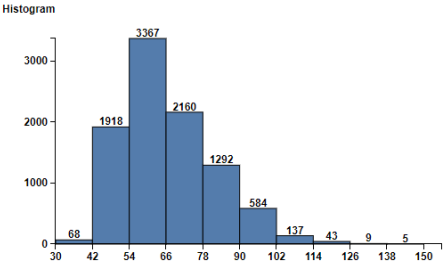
| Variables/statements | Mean | Standard deviation | | Frequency (n) |
|---|---|---|---|---|
| Age | 27. 06 | 10.38 | |   |
| Gender | 0.32 | 0.46 | | 0=6568, 1=3015 |
| Marital status | 0.27 | 0.44 | | 0=6995, 1=2588 |
| Height | 168.03 | 9.13 | |   |
| Bodyweight | 66.21 | 14.81 | |   |
| Education | 2.75 | 0.64 | | 0=34, 1=528, 2=1670, 3=6947, 4=404 |
| Working status | 0.35 | 0.48 | | 0=6240, 1=33431 |
| Do you have a disease diagnosed by a doctor? | 0.14 | 0.35 | | 0=8235, 1=1348 |
| Do you exercise regularly? | 0.42 | 0.49 | | 0=5551, 1=4032 |
| Income rate | 3.01 | 1.54 | | 1=2557, 2=1072, 3=1898, 4=2182, 5=1547, 6=327 |
| Do you think bread is a portion of healthy food? | 0.49 | 0.50 | | 0=4874, 1=4709 |
| Grain bread (mixed, grain, wholewheat, rye, oat, corn) | 0.45 | 0.50 | | 0=5311, 1=4272 |
| White bread, pita, lavash (wheat flour) | 0.14 | 0.35 | | 0=8219, 1=1364 |
| Sourdough, dough bread (wheat, wholewheat, grain) | 0.20 | 0.40 | | 0=7709, 1=1874 |
| Wholewheat bread, pita, lavash (wholewheat flour) | | 0.22 | 0.41 | 0=7510, 1=2073 |
| Increase the durability of bread | | 0.66 | 0.48 | 0=3307, 1=6276 |
| Increasing the nutritional value | | 0.25 | 0.44 | 0=7152, 1=2431 |
| To give aroma and flavor | | 0.31 | 0.46 | 0=6580, 1=3003 |
| Correcting and improving the appearance | | 0.36 | 0.48 | 0=6167, 1=3416 |
| Delay staling | | 0.70 | 0.46 | 0=2911, 1=6672 |
| Causes allergies | | 0.03 | 0.17 | 0=9294, 1=289 |
| Causes obesity | | 0.54 | 0.50 | 0=4421, 1=5162 |
| Causes other health problems | | 0.21 | 0.41 | 0=7607, 1=1976 |
| Causes an increase in cholesterol | | 0.10 | 0.29 | 0=8667, 1=916 |
| Does not cause health problems | | 0.05 | 0.21 | 0=9148, 1=435 |
| If the bread is crumbly | | 0.39 | 0.49 | 0=5865, 1=3718 |
| If the bread is moldy | | 0.70 | 0.46 | 0=2898, 1=6685 |
| If the bread is hard | | 0.49 | 0.50 | 0=4848, 1=4735 |
| If the bread is hard and crumbles easily | | 0.45 | 0.50 | 0=5234, 1=4349 |
| If the appearance of the bread is distorted | | 0.31 | 0.46 | 0=6593, 1=2990 |
| If the appearance of the bread has changed | | 0.39 | 0.49 | 0=5844, 1=3739 |
| If it is not consumed on the day, it is taken | | 0.09 | 0.29 | 0=8698, 1=885 |
| If the smell of the bread has changed | | 0.48 | 0.50 | 0=5003, 1=4580 |
| If the taste of the bread has changed | | 0.45 | 0.50 | 0=5289, 1=4294 |
| Wholewheat bread should be preferred instead of white bread to reduce the risk of obesity, heart, and chronic diseases | | 3.86 | 0.85 | 1=165, 2=447, 3=1880 4=5178, 5=1913 |
| Bread strengthens the immune system | | 2.69 | 1.01 | 1=1274, 2=2761, 3=3465 4=1833, 5=250 |
| Bread regulates the digestive system | | 2.76 | 1.03 | 1=1157, 2=2752, 3=3202 4=2209, 5=263 |
| Wholewheat bread is healthier | | 3.88 | 0.78 | 1=122, 2=485, 3=1406 4=6030, 5=1540 |
| White bread is unhealthy | | 3.43 | 1.06 | 1=293, 2=2023, 3=1786 4=4197, 5=1284 |

Table 1 (continued)
Descriptive statistics of the variables/statements

| | | | |
|---|---|---|---|
| Eating bread makes you gain weight | 3.28 | 1.20 | 1=451, 2=3164, 3=644 4=3894, 5=1430 |
| Eating too much bread makes you gain weight | 4.35 | 0.71 | 1=73, 2=219, 3=228 4=4843, 5=4220 |
| Bread is a source of energy | 3.39 | 1.06 | 1=522, 2=1797, 3=1575 4=4809, 5=880 |
| Consuming bread keeps you full | 3.56 | 1.07 | 1=484, 2=1658, 3=656 4=5573, 5=1212 |
| Additives used in bread making are harmful to our health | 3.84 | 0.87 | 1=117, 2=618, 3=1988 4=4855, 5=2005 |
| Bakery | 0.55 | 0.50 | 0=4314, 1=5269 |
| Grocer | 0.15 | 0.36 | 0=8155, 1=1428 |
| Buffet | 0.01 | 0.10 | 0=9491, 1=92 |
| I do it myself at home | 0.07 | 0.25 | 0=8932, 1=651 |
| Municipal outlet | 0.02 | 0.15 | 0=9362, 1=221 |
| Market | 0.20 | 0.40 | 0=7661, 1=1922 |
| White bread | 0.46 | 0.50 | 0=5179, 1=4404 |
| Pita | 0.67 | 0.47 | 0=3147, 1=6436 |
| Lavash (with wheat flour) | 0.46 | 0.50 | 0=5178, 1=4405 |
| Sourdough/dough bread (wheat, wholewheat grain) | 0.13 | 0.34 | 0=8317, 1=1266 |
| Grain bread (mixed grain, wholewheat, rye, oat, corn) | 0.20 | 0.40 | 0=7702, 1=1881 |
| Wholewheat bread | 0.21 | 0.41 | 0=7551, 1=2032 |
| Being close to reach | 0.51 | 0.50 | 0=4654, 1=4929 |
| Size | 0.03 | 0.18 | 0=9258, 1=325 |
| Packaging | 0.04 | 0.19 | 0=9244, 1=339 |
| Company name | 0.01 | 0.09 | 0=9505, 1=78 |
| View of bread | 0.05 | 0.22 | 0=9107, 1=476 |
| Producing quality bread | 0.10 | 0.30 | 0=8645, 1=938 |
| Sellers are smiling | 0.00 | 0.06 | 0=9549, 1=34 |
| Additive in bread | 0.03 | 0.16 | 0=9319, 1=264 |
| The calorie level of bread | 0.02 | 0.14 | 0=9391, 1=192 |
| Easy to find | 0.04 | 0.19 | 0=9212, 1=371 |
| To be salt-free | 0.01 | 0.07 | 0=9533, 1=50 |
| Being hot and fresh | 0.09 | 0.29 | 0=8719, 1=864 |
| To be well cooked | 0.06 | 0.24 | 0=8977, 1=606 |
| Being cooked in a wood oven | 0.03 | 0.17 | 0=9296, 1=287 |
| Produced/sold in a hygienic environment | 0.05 | 0.22 | 0=9096, 1=487 |
| What do you think about the quality of the bread you consume? | 3.60 | 0.79 | 1=68, 2=314, 3=4330 4=3573, 5=1298 |
| The manufacturer's disregard for quality | 0.45 | 0.50 | 0=5283, 1=4300 |
| Uneducated bakers | 0.06 | 0.24 | 0=8986, 1=597 |
| Presence of excessive and unconscious additives in bread | 0.27 | 0.45 | 0=6961, 1=2622 |
| Bread not cooked well | 0.05 | 0.22 | 0=9103, 1=480 |
| Bakers not paying attention to cleanliness | 0.08 | 0.26 | 0=8863, 1=720 |
| Poor quality of flour used in bread production | 0.07 | 0.26 | 0=8870, 1=713 |
| Using bleach in bread making | 0.06 | 0.25 | 0=8966, 1=617 |
| Bread is tasteless | 0.03 | 0.18 | 0=9261, 1=322 |
| How many slices of bread do you eat per day? | 2.05 | 1.12 | 0=386, 1=3228, 2=2832 3=1792, 4=1345 |
| Do you eat bread with meals? | 0.81 | 0.39 | 0=1838, 1=7745 |
| Soup | 0.69 | 0.46 | 0=2988, 1=6595 |
| Slops | 0.39 | 0.49 | 0=5896, 1=3687 |
| Meat, chicken, and rice | 0.17 | 0.38 | 0=7934, 1=1649 |
| Rice and pasta | 0.02 | 0.13 | 0=9420, 1=163 |
| I never consume | 0.03 | 0.17 | 0=9285, 1=298 |
| At breakfast | 0.60 | 0.49 | 0=3875, 1=5708 |
| At lunch | 0.08 | 0.28 | 0=8793, 1=790 |
| At snacks | 0.01 | 0.11 | 0=9456, 1=127 |
| At the dinner | 0.28 | 0.45 | 0=6923, 1=2660 |
| Bread hardening and crumbling | 0.45 | 0.50 | 0=5241, 1=4342 |
| Changing the taste of bread | 0.06 | 0.23 | 0=9053, 1=530 |
| Bread molding | 0.28 | 0.45 | 0=6918, 1=2665 |
| If not consumed that day | 0.09 | 0.28 | 0=8753, 1=830 |
| If the appearance of the bread has changed | 0.07 | 0.25 | 0=8944, 1=639 |
| I make breadcrumbs, crusty bread, etc. | 0.39 | 0.49 | 0=5895, 1=3688 |
| I use it dry | 0.29 | 0.45 | 0=6799, 1=2784 |
| I feed the animals | 0.60 | 0.49 | 0=3877, 1=5706 |
| I use it as a meatball paste | 0.46 | 0.50 | 0=5135, 1=4448 |
| I give the bread to the milkman and the porter | 0.09 | 0.28 | 0=8748, 1=835 |
| I do not evaluate it in any way, and I throw it away | 0.10 | 0.31 | 0=8588, 1=995 |
| I use it in soup and food | 0.37 | 0.48 | 0=6009, 1=3574 |
| I give to what is needed | 0.06 | 0.24 | 0=8996, 1=587 |
| I keep it in the freezer | 0.17 | 0.38 | 0=7964, 1=1619 |
| I consume it by heating | 0.29 | 0.45 | 0=6806, 1=2777 |
| I keep it in the fridge | 0.19 | 0.40 | 0=7725, 1=1858 |

*Correlation Analysis*

In statistical terminology, Spearman's rank correlation coefficient or Spearman's ρ, defined after Charles Spearman and often presented as {rho} in Greek, refers to the non-parametric measure of a rank correlation (statistical dependence between the rank of two variables). It gives the degree of relationship between two variables using a monotonic function. The Spearman correlation

between the two variables is equal to the Pearson correlation between these two variables; While Pearson's correlation reveals linear relationships, Spearman's correlation presents monotonic relationships (whether linear or not). In the absence of repeated data values, a perfect Spearman correlation of +1 or -1 occurs when each variable is a perfectly monotonic function. Conceptually, the Spearman correlation between two variables is high when the observations have similar (or identical for a correlation of 1) order between the two variables (i.e., the relative position label of the observations within the variable: 1st, 2nd, 3rd, etc.). is happening. Conversely, variables and observations are low when the two variables are different (or the opposite for a -1 correlation). The Spearman coefficient is suitable for both continuous and discrete ordinal variables. The p-value (two-sided) for these columns expresses the probability that an uncorrelated system will produce at least an extreme degree of correlation if the mean of the correlation is zero (Anonymous, 2021). At this stage, the nodes used in the KNIME platform are listed below (Figure 3).

First, it was aimed to reveal whether there is a relationship between the level of individuals related to bread and their demographic characteristics (Table 2).

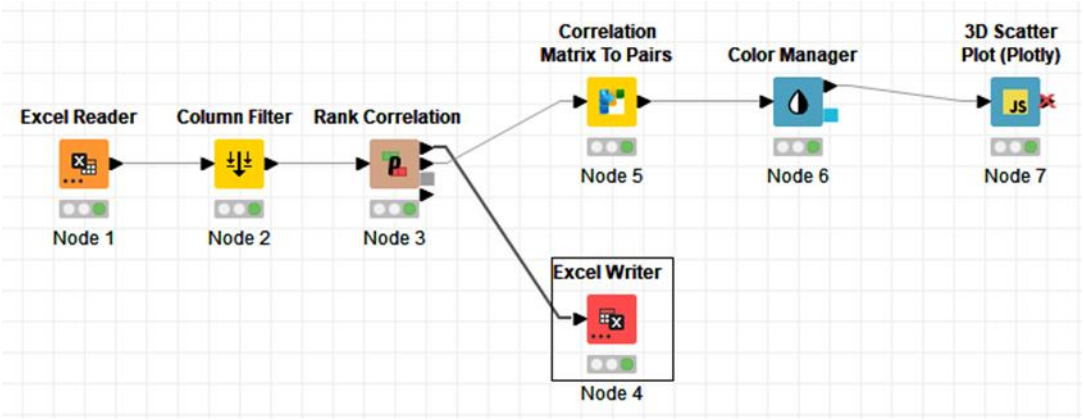



Figure 3

Workflow used in the KNIME platform for correlation analysis

Table 2

The relationship between the knowledge level of individuals about the healthiest of bread and their socio-demographic features

| | Consumer opinions about the healthiest type of bread | | | |
|---|---|---|---|---|
| | Grain bread | White bread, pita, lavash | Sourdough, dough bread | Wholewheat bread, pita, lavash |
| Age | -0.10*** | -0,09*** | 0,17 | 0,03*** |
| Gender | -0,09*** | 0.11*** | -0.01 | 0.02** |
| Marital status | -0.09*** | -0.06*** | 0.14 | 0.04*** |
| Height | -0.04*** | 0.08*** | -0.02** | -0.00 |
| Body weight | -0.07*** | 0.00 | 0.04*** | 0.04*** |
| Education | 0.05*** | -0.05*** | 0.03*** | -0.04*** |
| Working status | -0.06*** | 0.00 | 0.07*** | -0.00 |
| Income rate | -0.05*** | -0.04*** | 0.09 | 0.00 |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

There is usually a negative relationship with a low correlation coefficient between the socio-demographic characteristics of the consumers and the bread types they think are the healthiest. It turns out that the socio-demographic characteristics of the consumers and the characteristics of the health status of various bread types differ. Adebayo et al. (2017) stated that the demands and preferences of individuals belonging to different ethnic groups residing in Finland for healthy bread and food products also differ significantly. Sandvik et al. (2017) comparatively analyzed the situation between rye bread consumption and the expectation of consuming healthier products among young and old consumers in Sweden. They revealed that the structure and color (light and dark) of rye bread effectively form health properties. Demirtaş et al. (2018) stated that white bread is widely produced and consumed in Turkey, and regional consumption is also typical. Sarica et al. (2021), in a study they conducted in Turkey, found that insufficient control of the mother and father's occupation, monthly income, and bakery products were important in bread consumption. Therefore, it can be stated that the amount of bread consumption decreases with the increase in income. Sarica et al. (2021) also confirm this inference.

The relationships between the socio-demographic characteristics of the individuals and the additive they use in bread making are also examined (Table 3). The socio-demographic characteristics and various expressions of individuals about the additives used in bread

making are mostly positive, and statistically significant, but this relationship had a low ρ coefficient. Simmons et al. (2014) and Bacarea et al. (2021) declared that highly processed foods, which are calorie-dense and rich in carbohydrates, lipids, flavor enhancers, and food additives, are becoming popular among children and adolescents. It is emphasized that this popularity also continued to increase insidiously due to the lack of targeted education of the population. Loloei et al. (2019) emphasized that individuals with a relatively higher level of education can catch the opportunity to learn at a higher level, their awareness increases, and they can better understand the harmful effects of additives that are not allowed in bread.

Table 3
Correlation relationship between socio-demographic characteristics and bread additive

| Variables | Opinions on food additives used in bread making | | | | |
|---|---|---|---|---|---|
| | Increase the durability of bread | Increasing the nutritional value | To give aroma and flavor | Correcting and improving the appearance | Delay staling |
| Age | 0.07*** | -0.09*** | -0.03*** | -0.01 | -0.02* |
| Gender | -0.06*** | 0.02* | -0.02** | 0.04*** | -0.02** |
| Marital status | 0.05*** | -0.06*** | -0.05*** | -0.01 | -0.02** |
| Height | -0.04*** | -0.01 | -0.01 | 0.01 | 0.00 |
| Body weight | -0.01 | -0.03*** | -0.03*** | 0.02** | -0.01 |
| Education | 0.08*** | -0.04*** | 0.07*** | -0.00 | 0.07*** |
| Working status | 0.03*** | -0.05*** | -0.01 | -0.01 | -0.02** |
| Income rate | 0.05*** | -0.07*** | -0.01 | -0.01 | 0.03*** |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

The possible effects of additives used in bread making on individuals' health and socio-demographic characteristics are examined (Table 4). It is clarified that the correlation relationship between the variables in these groups is mostly negative, and they had low correlation coefficients. It can be stated that there is an awareness among individuals that there is a relationship between the additives used in bread and various health problems, albeit at a certain level. It can be deduced that the additives in question contribute to the formation of allergies and obesity and that they are one of the crucial reasons for the appearance of cholesterol and other health problems. It is underlined that awareness of the negative effects of some synthetic food additives has fueled high consumer demand for clean-label bread products (Cappelli et al., 2020). This is also confirmed in similar studies (Montagnese et al., 2015; Vandevijvere et al., 2017).

Table 4
Interaction of bread additives with possible health effects and socio-demographic characteristics

| Variables | Opinions on bread additives with possible health effects | | | | |
|---|---|---|---|---|---|
| | It causes allergies | It causes obesity | It causes other health problems | It causes an increase in cholesterol | It does not cause health problems |
| Age | 0.05*** | -0.01* | 0.03*** | -0.10*** | -0.00 |
| Gender | -0.03*** | -0.01 | -0.02 | 0.02** | 0.06*** |
| Marital status | 0.03*** | 0.02** | 0.01 | -0.08*** | -0.01* |
| Height | -0.01 | -0.03*** | 0.00 | 0.01 | 0.04*** |
| Body weight | -0.02** | 0.03*** | -0.03*** | -0.03*** | 0.03 |
| Education | 0.03*** | -0.05*** | 0.03*** | 0.01 | -0.03*** |
| Working status | 0.01 | 0.00 | -0.01 | -0.04*** | 0.02* |
| Income rate | 0.02* | -0.01 | -0.00 | -0.03*** | 0.00 |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

Stale aging occurs with the hardening of breadcrumbs, which starts during the cooling process of bread products and gradually hardens, dries, and crumbles during storage, and the crust becomes soft and leathery (Dong and Karboune, 2021). The correlation between understanding that bread is too stale for consumption and some socio-demographic characteristics is also evaluated (Table 5). Some variables are positive, some are negative, and there is no correlation between the remaining few variables. The correlation coefficients are also low among the variables analyzed at this stage. Although there is a negative correlation between age and bread being hard enough, it is defined that the correlation coefficient (ρ) was relatively higher than the other coefficients.

Table 5
The correlation between understanding that bread is too stale for consumption and socio-demographic features

| Variables | Perceptions of bread's stale for consumption | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | If the bread is crumbly | If the bread is moldy | If the bread is hard | If the bread is hard and crumbles easily | If the appearance of the bread is distorted | If the appearance of the bread has changed | If it is not consumed on the day, it is taken | If the smell of the bread has changed | If the taste of the bread has changed |
| Age | 0.02** | 0.07*** | -0.08*** | -0.05*** | -0.02** | -0.04*** | -0.01 | 0.02** | 0.02 |
| Gender | -0.02** | -0.05** | 0.03*** | -0.03*** | -0.03*** | -0.04*** | 0.03*** | -0.06*** | -0.04*** |
| Mrt. St. | 0.02** | 0.07*** | -0.08*** | -0.05*** | -0.03*** | -0.05*** | -0.01 | 0.02* | 0.02 |
| Height | -0.03*** | -0.03*** | 0.03*** | -0.02** | -0.03*** | -0.02** | 0.02** | -0.04*** | -0.03*** |
| Body weight | -0.01 | 0.00 | -0.01 | -0.05*** | -0.03*** | -0.04*** | -0.00 | -0.04*** | -0.02* |
| Education | -0.04*** | 0.01 | 0.01 | 0.04*** | 0.05*** | 0.06*** | -0.02** | 0.05*** | 0.03*** |
| Working status | 0.02** | 0.04*** | -0.02** | -0.01 | 0.00 | -0.00 | 0.01 | 0.01 | 0.01 |
| Income rate | -0.01 | 0.05*** | -0.03*** | -0.02* | -0.00 | -0.01 | 0.01 | 0.01 | 0.01 |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

As the working status and income level increase, the correlation coefficient between the perceptions of bread consumption seems to have a positive relationship. This reveals a positive relationship between the statements about the staleness of bread as the income level of the individual's increases and the opportunity to work improves. The correlation between various socio-demographic characteristics and some bread and health-related characteristics is also analyzed (Table 6).

Table 6
Correlation between various socio-demographic characteristics and some bread and health-related attributes

| Variables | Bread and health-related characteristics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wholewheat bread should be preferred instead of white bread to reduce the risk of obesity, heart, and chronic diseases | Bread strengthens the immune system | Bread regulates the digestive system | Wholewheat bread is healthier | White bread is unhealthy | Eating bread makes you gain weight | Eating too much bread makes you gain weight | Bread is a source of energy | Consuming bread keeps you full | Additives used in bread making are harmful to our health |
| Age | 0.05*** | -0.00 | -0.01 | 0.04*** | 0.15 | 0.13 | -0.01 | -0.13*** | -0.08*** | 0.11 |
| Gender | -0.11*** | 0.03*** | 0.03*** | -0.05*** | -0.06*** | -0.06*** | 0.08*** | -0.08*** | 0.11 | -0.08*** |
| Marital status | 0.04*** | -0.02** | -0.04** | 0.03*** | 0.12 | 0.13 | 0.00 | -0.14*** | -0.06*** | 0.10 |
| Height | -0.07*** | 0.03*** | 0.03*** | -0.03*** | -0.04*** | 0.02** | -0.04*** | 0.04*** | 0.06*** | -0.04*** |
| Body weight | 0.01 | -0.00 | -0.00 | 0.03*** | 0.06*** | 0.12 | 0.05*** | -0.03*** | -0.02** | 0.02** |
| Education | 0.05*** | -0.02* | 0.01 | 0.04*** | 0.03*** | -0.11*** | 0.06*** | 0.07*** | -0.02 | 0.04*** |
| Working status | 0.01 | -0.03*** | -0.04*** | 0.03*** | 0.08*** | 0.09 | -0.01 | -0.10*** | -0.04*** | 0.03*** |
| Income rate | 0.04*** | -0.03*** | -0.01 | 0.04*** | 0.11 | 0.07*** | 0.04*** | -0.06*** | -0.07*** | 0.07*** |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

Sandvik et al. (2018) state that most consumers find the bread healthy. A quarter of the participants stated that they had no idea about the relation of bread to health and that most of the consumers in this group had a low level of education. It is found that consumers' cues are more important than labels in their perception of healthy bread. The study tried to define the consumers' perceptions of bread related to health by discovering which quality attributes related to bread and health and whether there were differences in terms of age, gender, and education level. Three-quarters of consumers rank bread as healthy among the course, like whole grain, fibre-rich, sourdough, crunchy, less sugar, dark, rye, and seed. They stated that such terms are in interaction. Concepts such as trademark, homemade, and cores are also discussed at this point. Bread is perceived as healthy mainly because they contain fiber, is good for the stomach, saturates well, and has beneficial glycemic properties. One of the difficulties in defining healthy bread, especially among consumers with a low level of education, is a preference for consumption. It is suggested that many of the health effects that are important to consumers cannot be conveyed on food packages, and therefore consumers should use their clues to identify these characteristics. This is especially true if bread is labeled, for example, as sourdough bread or rye bread despite its low content. They are summarized as it may cause misdirection of consumers.

In this study, there is mostly a positive correlation between the variables discussed here, whereas the correlation coefficient is small, as in the other sections. It is revealed that there is a relatively high negative correlation of 0.11 only between gender and the variable that whole wheat bread should be used instead of white bread to reduce obesity, heart, and chronic diseases. It can be stated that this perception is especially higher in women. As the income level of individuals increases and some symptoms of diseases that differ according to various health reasons begin to appear, the perception of consumption towards bread varieties with low calories and relatively high nutritional value develops. While most consumers buy bread from bakers, grocers, and greengrocers, it is observed that the number of consumers who mark the option to make it myself at home remains very low. In 2020, when a heavy closure period was passed due to the covid-19 epidemic, it is represented that although bread making at home has increased to a certain extent, most consumers still buy bread from outside the home in Turkey.

It is defined that most individuals prefer to consume pita, white bread, lavash (with wheat flour) (Table 1). It is discovered that there are statistically significant relationships between the socio-demographic characteristics of individuals and the correlation relationship between the types of bread they frequently consume, especially between some variables (Table 7). It is observed that as age, body weight, education, and income level increase, consumption of white bread, pita, and lavash decreases, while preference for grain bread and wholewheat increases. It is observed that there is a similar development to the above trend as the working opportunities of individuals improve.

Table 7
Correlation between bread types consumed and socio-demographic characteristics

| Variables | Bread types consumed | | | | | |
|---|---|---|---|---|---|---|
| | White bread | Pita | Lavash (with wheat flour) | Sourdough/dough bread (wheat, wholewheat grain) | Grain bread (mixed grain, wholewheat, rye, oat, corn) | Whole-wheat bread |
| Age | -0.15*** | -0.14*** | -0.15*** | 0.15 | 0.04*** | 0.01 |
| Gender | 0.08*** | 0.07*** | 0.08*** | -0.02 | -0.07*** | -0.02 |
| Marital status | -0.09*** | -0.08*** | -0.09*** | 0.10 | 0.01 | 0.02** |
| Height | 0.03*** | 0.02** | 0.03*** | -0.03*** | -0.00 | -0.01 |
| Body weight | -0.06*** | -0.04*** | -0.06*** | 0.03*** | 0.02** | 0.03*** |
| Education | -0.07*** | -0.07*** | -0.07*** | 0.03*** | 0.06*** | 0.00 |
| Working status | -0.07*** | -0.06*** | -0.07*** | 0.04*** | 0.04*** | 0.01 |
| Income rate | -0.10*** | -0.09*** | -0.10*** | 0.07*** | 0.05*** | 0.01 |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

At this stage, although it is defined that there are statistically significant, both negative and positive correlation relationships among many variables, the high correlation coefficients between age and income level and the types of bread consumed reveal that the difference is more visible. It is explored that there is a negative correlation between the age of the consumer and the types of bread consumed. This is also an expected situation. As the age of the individual increases, it appears that there is a significant decrease in the amount of consumption of bread types (Figure 4).

These inferences, Demirtaş et al. (2018), Sarica et al. (2021), and Dong and Karboune (2021), are also like the findings and literature reports.

The interaction between the socio-demographic characteristics of consumers and the points they pay attention to when buying bread is examined below (Table 8).

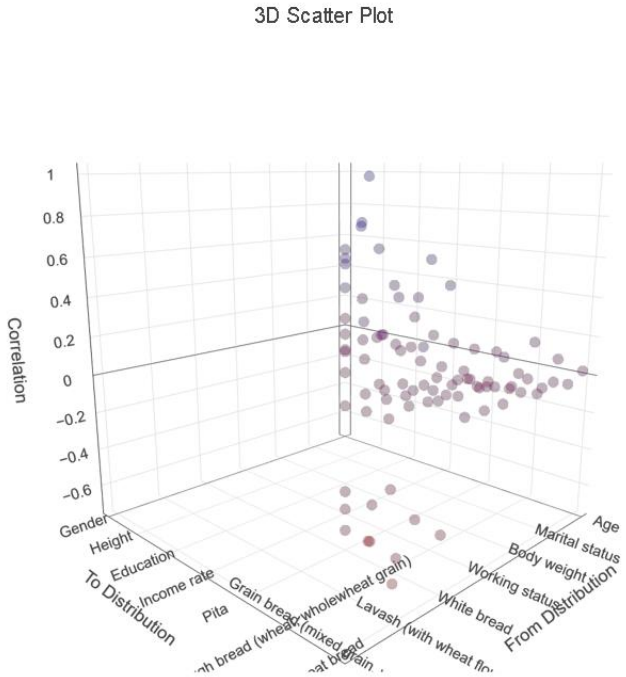



Figure 4

Scatter plot graph for correlation values intended for bread types consumed and socio-demographic features

Table 8

Relationship between considerations when buying bread and socio-demographic characteristics of the consumers

| Variables | Socio-demographic characteristics | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Age | Gender | Marital status | Height | Bodyweight | Education | Working status | Income rate |
| Being close to reach | -0.09*** | 0.05*** | -0.06*** | 0.03*** | 0.06 | 0.00 | -0.04*** | -0.05*** |
| Size | -0.02** | -0.01 | -0.03*** | -0.01 | -0.01 | -0.01 | -0.01 | -0.02*** |
| Packaging | 0.04*** | -0.02** | 0.03*** | -0.02** | 0.01 | -0.03*** | 0.02** | 0.00 |
| Company name | 0.00 | 0.00 | -0.01 | 0.00 | 0.00 | 0.02* | 0.02* | 0.01 |
| View of bread | -0.03*** | -0.01 | -0.02** | -0.01 | -0.02*** | 0.02** | -0.02 | -0.01 |
| Producing quality bread | 0.01 | -0.01 | -0.00 | -0.01 | 0.00 | 0.02** | -0.01 | 0.01 |
| Sellers are smiling | -0.01 | 0.02** | -0.00 | -0.00 | 0.00 | -0.00 | 0.03*** | 0.01 |
| Additive in bread | -0.01 | -0.01 | -0.01 | 0.00 | 0.00 | 0.01 | -0.01 | -0.01 |
| The calorie level of bread | -0.02*** | 0.03*** | -0.02 | 0.03*** | 0.03*** | -0.01 | -0.02** | -0.02 |
| Easy to find | -0.03*** | 0.02** | -0.03*** | 0.02 | 0.01 | -0.00 | -0.02** | -0.02* |
| To be salt-free | 0.04*** | -0.00 | 0.02*** | 0.00 | 0.01 | -0.02** | -0.01 | 0.00 |
| Being hot and fresh | -0.05*** | 0.00 | -0.03*** | -0.01 | -0.01* | 0.00 | -0.04*** | -0.03*** |
| To be well cooked | -0.01 | -0.00 | -0.02** | -0.02 | -0.01 | -0.01 | -0.04*** | -0.01 |
| Being cooked in a wood oven | 0.02 | 0.00 | 0.01 | -0.01 | -0.00 | -0.02** | 0.01 | 0.00 |
| Produced/sold in a hygienic environment | -0.00 | -0.03*** | -0.01 | -0.03*** | -0.02* | -0.01 | -0.04*** | -0.01 |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

When the correlation coefficients between the socio-demographic characteristics of the consumers and the subjects taken into consideration when purchasing bread are examined, it is observed that although there are negative and positive correlation coefficients, there is no significant correlation coefficient. It is clarified that the correlation coefficient values are quite small. In this study, various socio-demographic characteristics of individuals, access to places where bread is purchased, packaging, calorie level of bread, easy availability, salt-free, hot, fresh, well-cooked, and hygienically produced and sold found to be more related than other characteristics. Akdemir et al. (2020) emphasizes that the factors of being close to home, freshness, hygiene, and being of good quality come to the fore in choosing a place where bread is purchased. Sandvik et al. (2017) determined that young consumers generally prefer soft, juicy texture (low moisture absorption) and sweet flavored bread.

On the other hand, bread with this content was also perceived as the least healthy bread type, not rye bread. It was defined that this situation is associated with eating mainly white bread or a sweet loaf of bread during childhood and finding convenience and familiarity in food selection, especially among males. The high level of education of the individuals, being a woman and expressing the importance of health, ethical awareness, and natural

content in food selection was associated with the preference for healthier, chewy resistant, and sour-flavored rye bread, especially among young consumers. It is clarified that older consumers often like whole-grain rye-rich bread slightly more. On the other hand, individuals in the elderly group liked soft white bread more, had lower education levels, were born, and raised in Sweden, were associated with less consumption of dark, chewy bread in childhood, and the importance of natural ingredients and food choice were negatively related. The combination of sensory properties such as light color and soft texture led to the perception that the bread is less healthy than rye bread, while the opposite was found for healthier bread and rye bread.

The connection between the socio-economic features of the consumers and the quality of the bread they consume is evaluated (Table 9).

Table 9
The connection between socio-demographic features of the consumers and their opinions on the quality of the bread

| Variables | Socio-demographic characteristics | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Age | Gender | Marital status | Height | Bodyweight | Education | Working status | Income rate |
| Opinions on quality of bread | -0.01 | 0.04*** | -0.01 | 0.05*** | 0.03*** | -0.03*** | 0.01 | 0.01 |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

Although there is a statistically significant correlation between some socio-demographic characteristics of the consumers and the quality of the bread they consume and a negative correlation between some of their characteristics, it is observed that these correlation coefficients are quite small, as in most of the previous section. On the other hand, there is a positive correlation between consumers' gender, height, body weight, and bread quality thoughts. Amini-Rarani et al. (2021) examined the role of social health and demographic factors on bread quality in Iran. They found that low social characteristics of individuals increase the probability of low-quality bread production, while illiteracy or low education level increases the risk of low-quality bread production. It is reported that social health and responsibility, awareness, and empathy are associated with bread quality. Health policies have been referred to the social health of bakeries to increase the quality of bread. In addition, this study covers low and medium social health, 7-12 years of education; it was emphasized that lower work experience, rental property status, and living in the south increased the likelihood of baking poor quality bread. Only one factor was determined to be in a protective position, including the central location. The research conducted by Eglite and Kunkulberga (2017) aims to determine the trends in bread selection and consumption of consumers in Latvia. It was discovered that the reasons for the consumer preference related to the quality and price of the bread and the trust and behavior of the consumers are different for different types of bread. While the determining factor in the selection of wheat bread was the price, the choice of rye bread was determined by the previous experience, namely the producer of the consumed bread. It is thought that consumers can increase their bread consumption if more delicious and high-quality bread is produced.

In the following stage, the correlation between the thought of why the quality of the consumed bread is not satisfactory and the socio-demographic characteristics of the consumers are also analyzed (Table 10).

Table 10
Links between socio-demographic attributes and the notion that the quality of bread is not sufficient

| Variables | Socio-demographic attributes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Age | Gender | Marital status | Height | Bodyweight | Education | Working status | Income rate |
| The manufacturer's disregard for quality | 0.01 | 0.04*** | -0.00 | 0.02** | 0.02** | -0.01 | 0.01 | 0.00 |
| Uneducated bakers | 0.05*** | 0.04*** | 0.04*** | 0.01 | 0.03*** | -0.01 | 0.02* | 0.02* |
| Presence of excessive and unconscious additives in bread | 0.02 | -0.01 | -0.00 | 0.01 | 0.00 | 0.02 | 0.00 | 0.01 |
| Bread not cooked well | 0.01 | 0.01 | 0.01 | -0.01 | 0.02 | -0.04*** | -0.00 | -0.00 |
| Bakers not paying attention to cleanliness | 0.02* | -0.05*** | 0.02** | -0.04*** | -0.01 | -0.02** | -0.03*** | 0.00 |
| Poor quality of flour used in bread production | -0.00 | 0.02 | -0.02* | -0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Using bleach in bread making | 0.05*** | -0.03*** | 0.03*** | -0.03*** | -0.01 | 0.02** | 0.03*** | 0.02** |
| Bread is tasteless | -0.03*** | -0.01 | -0.03*** | -0.01 | -0.01 | 0.02* | -0.03*** | -0.02* |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

At this stage, although it is discovered that there are negative correlations between some variables and positive correlations between others, the correlation coefficients between statistically significant variables are also found to be at a very low level. While there is a positive correlation between most of the socio-demographic characteristics of the consumers and the bread producers' disregard for quality, untrained bakers, the presence

of unknown or excessive additives in the bread content, the bread not baked well, the low quality of the flour used in the bread production, the bakers' lack of cleanliness. There is a negative correlation between the lack of importance and the poor quality of the bread. Dong and Karboune (2021) emphasized a continuing interest in optimizing post-production quality and extending the shelf life in relation to the preservation and enhancement of the economic and social values, flavors, and textural properties of bread a staple food product. Second, it has been the subject of numerous studies and reviews, in which different approaches and views are discussed. However, it was emphasized that the differences in freshness, flavor, and textural quality of bread are still a cause for concern in bread making. At the same time, the industry expects bread products with high-quality qualities and without synthetic ingredients that satisfy consumers' tastes and sustainable lifestyles. It was defined that it is very important to focus mainly on the quality profiles of bread, including flavor, rheological, textural, and sensory aspects. The linkage between consumers' daily eaten slices of bread and bread consumption in meals and some socio-demographic characteristics are also examined (Table 11). Although it is clarified that there is a statistically significant, negative, and positive correlation between these two groups of variables and the socio-demographic characteristics of consumers, the correlation coefficients are found to be quite small.

As the education level and income of the individual increase, the slice of bread eaten daily decreases, while the bread consumption increases relatively as the age increases, being married and working in a job because there is a positive correlation between them. Interestingly, as the education level and income increase, the consumption of bread with food decreases. However, with increasing age, being married, and increasing height and body weight, bread consumption with food increases.

This part of the study examines the connection between which food meals consumers consume with bread and which meals they mostly consume (Table 12).

Table 11
The connection between socio-demographic features of the consumers and their bread consumption in meals

| Variables | Socio-demographic attributes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Age | Gender | Marital status | Height | Bodyweight | Education | Working status | Income rate |
| Number of slices of bread eaten per day | 0.07*** | 0.25 | 0.08*** | 0.15 | 0.16 | -0.13*** | 0.05*** | -0.03*** |
| Eating bread with meals | 0.04*** | 0.11 | 0.04*** | 0.05*** | 0.07*** | -0.07*** | 0.01 | -0.02* |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

Table 12
The correlation between bread and the food or meals consumed meals the customers mostly consume

| Variables | Bread and food or meals consumed by the consumers | | | | |
|---|---|---|---|---|---|
| | Soap | Slops | Meat, chicken, and rice | Rice and pasta | I never consume |
| At breakfast | 0.01 | -0.02** | -0.10*** | -0.07*** | -0.21*** |
| At lunch | -0.01 | 0.02* | 0.03*** | 0.01 | -0.05*** |
| At snacks | -0.03*** | -0.03*** | -0.02** | -0.02 | -0.02** |
| At the dinner | 0.02** | 0.06*** | 0.13 | 0.08*** | -0.11*** |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

As expected, it is observed that bread is consumed more intensively at lunch and dinner along with slops, meat, chicken, and rice, rice, and pasta, and the correlation between these variables is therefore statistically significant. The most interesting and remarkable result is that the correlation between the variables that do not consume any bread at breakfast is negative, whereas the correlation coefficient is relatively high. On the other hand, a negative but statistically significant yet low correlation coefficient is determined between lunch and snack meals and the expression I never consume. In this process, it can be predicted that the rapidly changing living and working conditions and the active participation of women in working life have significant effects. Although there are important structural changes and breaks in all areas of working life and life in this covid 19 process, it is an inevitable reality that there are irreversible changes and developments in eating habits. Schwedhelm et al. (2018) found a high correlation between food products such as bread, margarine, butter, and cheese that are often eaten together.

On the other hand, they determined that there is a strong negative correlation between potatoes, pasta, rice, tea, and breakfast, which are easily substituted for each other. Charlebois et al. (2020) conducted a research study examining the eating habits of Canadians and highlighting important trends in food consumption patterns and showing the socio-economic motivations that affect food management practices today. It has been suggested that contemporary Canadians experience a disruption in mealtimes, an increase in snacking frequency, and an erosion of the desire or ability to cook. As these fragmented eating habits and disintegration of traditional food patterns represent a challenge for public health nutrition in Canada and are particularly relevant to changes in the provision of dietary guidance nationally, further research on this topic is recommended.

This last part of the study focuses on how the stale bread is determined, how stale bread is evaluated, and how the bread is stored (Table 13).

Table 13
Correlation between understanding and evaluation of stale bread and storage of bread

| Variables | Evaluating of stale bread | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | I make bread-crumbs, crusty bread, etc. | I use it dry | I feed the animals | I use it as a meatball paste | I give the bread to the milkman and porter | I do not evaluate it in any way. I throw it away | I use it in soup and food | I give to what is needed |
| Bread hardening and crumbling | 0.04*** | 0.02** | -0.00 | 0.07*** | -0.03*** | -0.05*** | 0.04*** | -0.00 |
| Changing the taste of bread | -0.01 | 0.01 | 0.03*** | -0.03*** | 0.01 | -0.02 | -0.00 | 0.01 |
| Bread molding | -0.03*** | -0.02** | -0.02** | -0.04*** | 0.00 | 0.06*** | -0.04*** | -0.03*** |
| If not consumed that day | -0.01 | -0.01 | 0.02** | 0.00 | 0.01 | -0.01 | -0.00 | 0.03*** |
| If the appearance of the bread has changed | 0.05*** | 0.05*** | 0.08*** | 0.06*** | 0.03*** | 0.04*** | 0.06*** | 0.04*** |
| I keep it in the freezer | 0.18 | 0.20 | 0.05*** | 0.22 | 0.03*** | -0.09*** | 0.21 | 0.11 |
| I consume it by heating | 0.12 | 0.16 | 0.03*** | 0.18 | 0.02** | -0.13*** | 0.28 | 0.12 |
| I keep it in the fridge | 0.15 | 0.20 | -0.02* | 0.19 | 0.05*** | -0.10*** | 0.24 | 0.12 |

*, **, *** denotes statistically significant at p<0.10, p<0.05, and p<0.01, respectively.

It is determined that the correlation between most of the variables related to the evaluation of stale bread and most of the variables related to how the stale bread is understood and how the bread is stored is statistically significant, both positive and negative. On the other hand, the correlation coefficients calculated in this section are also quite small. Concerning the staling of the bread; if the appearance of the bread is changed, it is defined that there is a positive correlation between the expressions of storing the bread in the refrigerator, consumption by heating and keeping the bread in the freezer, and all evaluation attitudes of stale bread. However, again about the staleness of the bread, it is determined that there is a negative correlation relationship between the change in taste, molding of bread, and all evaluation attitudes toward stale bread. In this case, it can be stated that consumers make as much effort as possible to consume bread in the absence of a negative phenomenon related to human health, especially in the perception of the staleness of bread. At this point, it is thought that a great effort is made to prevent the bread from being thrown away as garbage, and there is an important positive perception in this regard. However, in the staleness of bread, evaluation forms may affect human health, especially when it comes to microbial activities, consumption of bread, feeding to animals rather than human consumption, etc. These interpretations are approved by Demirtaş et al. (2018), Sarica et al. (2021), and Dong and Karboune (2021).

*Supervised Classification Models*

One of the most preferred data mining methods is organizing various data into predefined categories by applying classification (Patil and Shinde, 2020). Nguyen and Do (2020) compared many data mining techniques for training a large dataset for classification optimization. According to their study, Naïve Bayes algorithms could give the best prediction findings. The classification task defines the estimation of the target variable using the input variables. If a target is provided as part of the dataset, classification is a supervised task. Therefore, it is important to analyze the performance of supervised classification models before using them in a classification task. In the study, the performance of supervised classification models such as Decision Tree and Naive Bayes is evaluated using the KNIME Analytics platform. In both machine learning algorithms, firstly, consumers consider whether bread is healthy food, and secondly, how many slices of bread do you eat per day? The focus is on approaches for estimating expressions. In general, creating a classification model consists of two steps. The first is the training phase, where the model is created and the parameters of this data, called training data, are adjusted as it helps to build a model. The second is the testing phase, in which the learned model is applied to new data. The model is then evaluated according to its performance on the test data (Basha et al., 2018). In all models, 80% of the data is used for training and 20% for testing.

*Decision Tree Modeling*

A decision tree is a classification model that uses a tree-like structure to present multiple decision paths. Crossing each path and classifying an input sample leads to a different path. A Decision Tree is an algorithm that uses a supervised machine learning approach by repeatedly splitting data to solve regression and classification problems based on a given variable. The data is first divided into nodes, and then the tree's leaf represents the final decisions. The main purpose of the decision tree is to create a model that can be used to predict the target

variable by learning the simple decision rules obtained from the training data (Chauhan, 2020). The tree is created during a training process using training data. Leaf nodes express the name of the class, while the decision node is a non-leaf node (Eesa et al., 2015a; Eesa et al., 2015b). The decision tree handles categorical and numerical data. The nonlinear relationship between the arguments does not affect the efficiency of the tree (Tian et al., 2019). No preprocessing of data is required. However, the possibility of over-learning may arise when the tree is repeatedly rebuilt (Ibrahim and Abdulazeez, 2021).

*Naïve Bayes Modeling*

A Naïve Bayes model uses a probabilistic approach to classification. Bayes Theorem is used to understand the relationship between the input and the output class. Naïve Bayes is a probabilistic and statistical method based on the classification algorithm. It is a standard algorithm in machine learning applications as it offers a simple approach to all features contributing equally to the final decision. Computational efficiency equals this simplicity, making the Naive Bayes approach exciting and suitable for different fields. The basic component of the Naive Bayes classification is the prior, next, and class conditional probability (Wibawa et al., 2019). This method offers many benefits, such as being easy and very useful for large data sets. It can be used for binary and multiclass classification problems. Relatively less training data is required and can be used for both discrete and continuous data (Uddin et al., 2019). For example, this algorithm can easily filter spam and classify documents (Yaswanth and Riyazuddin, 2020).

*Performance Metrics*

Key performance metrics for result validation; Precision, Recall, F-Measure, True Positive (TP) Ratio, False Positive (FP) Ratio, ROC Area, Kappa Stats and Accuracy, etc. These performance measures help to understand the performance of a model better and clearly. Brief explanations of these performance estimators are presented below (Gupta et al., 2021). When a model is created, or existing models are used for a classification approach, that model's success is considered the number of correct predictions from all predictions made. However, this information only gives the accuracy of the classification. The confusion matrix alone is often not enough information to decide whether a model is good enough. True Positive (TP), False Positive (FP), True Negative (TN), False Negative (FN). True Positive (TP): Correctly predicted positive values. This indicates that the value of the actual class and the estimated class are the same. True Negative (TN): These are correctly predicted negative values. This indicates that the value of the actual class and the estimated class are the same. False Positive (FP): This value appears when your actual class and the predicted class conflict. False Negative (FN): This value appears when your actual class conflicts with the predicted class. While it is desired to increase the true positive and true negative areas, decreasing the false positive and false negative areas shows that the classification performance is good. Thanks to the confusion matrix, the following metrics can be calculated. Accuracy: Accuracy is the most intuitive performance measure and is the ratio of correctly predicted observations to total observations. If the model used has high accuracy, it can be considered that the model is the best. However, in cases where the number of false-positive and false-negative values is quite different, other parameters should be considered to evaluate the model's performance. Precision: Precision is the ratio of correctly predicted positive observations to the total predicted positive observations. This is also called Positive Predictive Value. Precision can be thought of as a measure of the precision of classifiers. Low sensitivity can also indicate many false positives. Recall, Sensitivity: The ratio of correctly predicted results to the total number of positives. It is the proportion of correctly predicted positive observations for all observations in the classification. It can be thought of as a measure of the integrity of the classifiers. Low sensitivity indicates a lot of false negatives. Specificity: In fact, it is an indicator of how many of the negative values are predicted as negative. F-score (F-measure): It is the harmonic mean of recall and precision. Therefore, it considers both false positives and false negatives. Looking at the F-score is more useful than looking at the accuracy value, especially in cases where there is an uneven class distribution. If false positives and false negatives occur in similar numbers, looking at the accuracy value give the best results for classification success. If the numbers of false positives and false negatives are very different, it is necessary to look at sensitivity and sensitivity. ROC area: Also known as the Receiver Operating Characteristic, it plots the performance measurement graph. The true-positive ratio is plotted against the false-positive ratio. ROC curves are widely adopted in machine learning to significantly visualize, organize, and measure performance. The area under the ROC curve is called the AUC (Area under the curve). Cohen's Kappa statistics: A measure that relates Observed Accuracy to Expected Accuracy. Kappa statistic is also used to evaluate classifiers among themselves.

*Comparison of Two Machine Learning Algorithms Findings*

First, the results of the two algorithms are compared to predict consumers' opinion of whether bread is healthy food. The numbers 1 and 0 represent yes and otherwise, respectively. Workflows of Decision Tree (Figure 5) and Naïve Bayes algorithms (Figure 6) in KNIME are represented. The confusion matrices and performance metrics of both algorithms are represented together in Table 14.

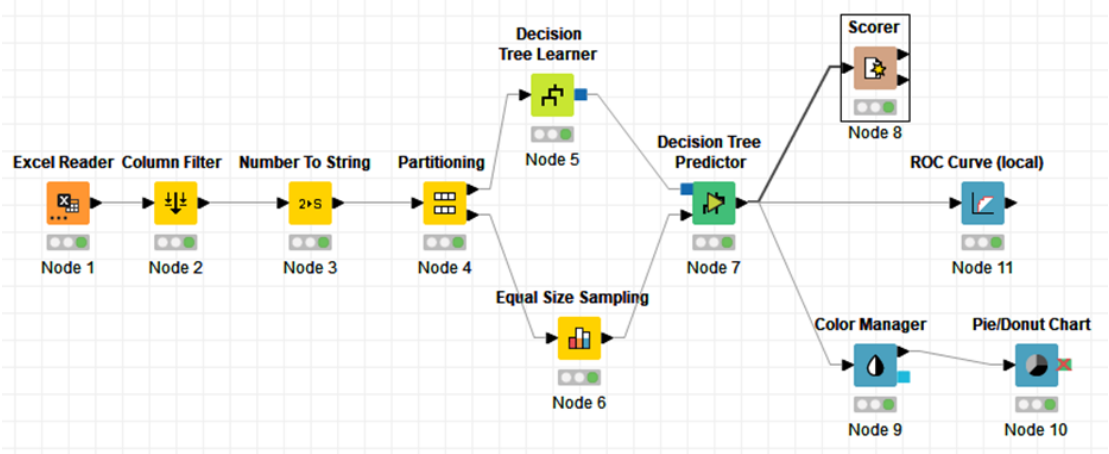



Figure 5
Workflow of Decision Tree defining consumers' perception of whether bread is a healthy food

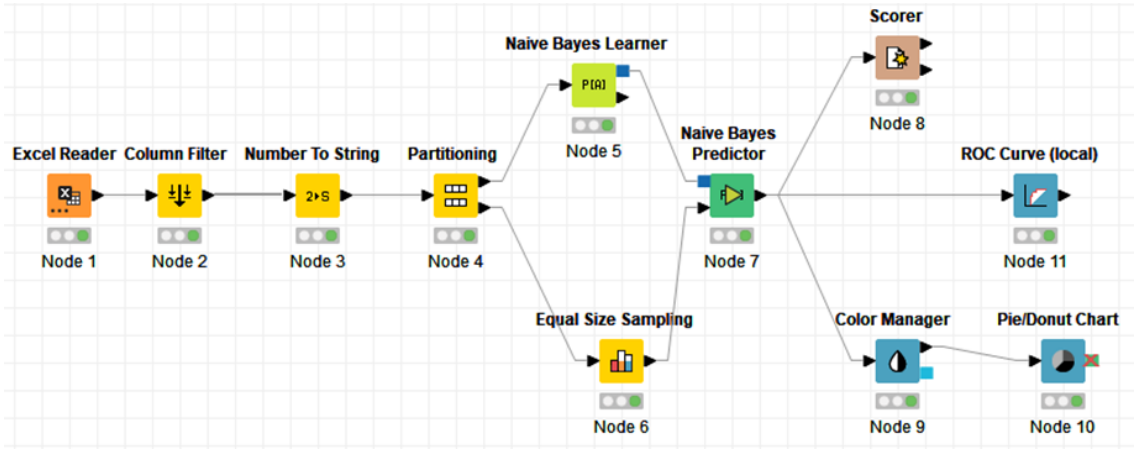



Figure 6
Workflow of Naïve Bayes describes consumers' perception of whether bread is a healthy food

Table 14
Confusion matrices and performance metrics for bread healthiness' perceptions

| Decision Tree | | Predicted value | | Accuracy | Performance metrics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Yes | Otherwise | | Sensitivity | Specificity | Precision | F-score | Cohen's Kappa |
| Actual value | Yes | 649 | 228 | 0.738 | 0.733 | 0.742 | 0.740 | 0.737 | 0.476 |
| | Otherwise | 236 | 657 | | 0.742 | 0.733 | 0.736 | 0.739 | |
| Naïve Bayes | | Predicted value | | Accuracy | Performance metrics | | | | |
| | | Yes | Otherwise | | Sensitivity | Specificity | Precision | F-score | Cohen's Kappa |
| Actual value | Yes | 621 | 155 | 0.744 | 0.651 | 0.838 | 0.800 | 0.718 | 0.488 |
| | Otherwise | 333 | 799 | | 0.838 | 0.651 | 0.706 | 0.766 | |

It can be stated that the findings obtained from the Naive Bayes algorithm in terms of many performance metrics, especially the accuracy measurement, are more consistent than the Decision Tree algorithm, and the predictive power is higher. In the Decision Tree algorithm, among 1306 correct predictions, the predictions of yes and other cases are approximately equal (Figure 7). In the Naive Bayes algorithm, within 1420 correct predictions, the yes option is estimated with an accuracy of 41% and the other case option with an accuracy of 59% (Figure 8). Furthermore, the ROC curves of the Decision Tree and Naive Bayes algorithms are quite similar (Figure 9 and Figure 10). The area value under the ROC curve is 0.7524 and 0.8383 for the Decision Tree and Naive Bayes algorithms, respectively. Therefore, it can be said that the Naive Bayes algorithm is slightly more successful than the Decision Tree modeling.

Second, the results of the two algorithms are compared to the statement, how many slices of bread do you eat per day? The numbers 0, 1, 2, 3, and 4 refer to no, one or two slices, three to four slices, five to six slices, or more than six slices in a day. Finally, workflows of Decision Tree (Figure 11) and Naïve Bayes algorithms (Figure 12) in KNIME are represented.

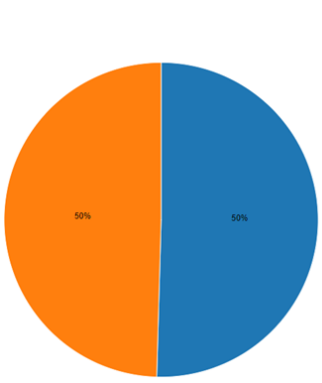



Figure 7
The prediction level of bread's perception of being healthy with the Decision Tree algorithm

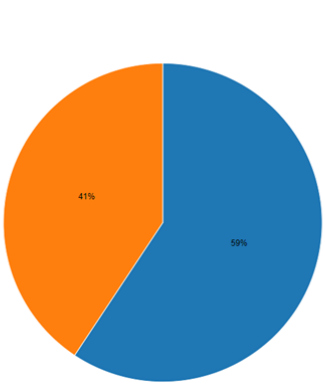



Figure 8
The prediction level of bread's perception of being healthy with the Naïve Bayes algorithm

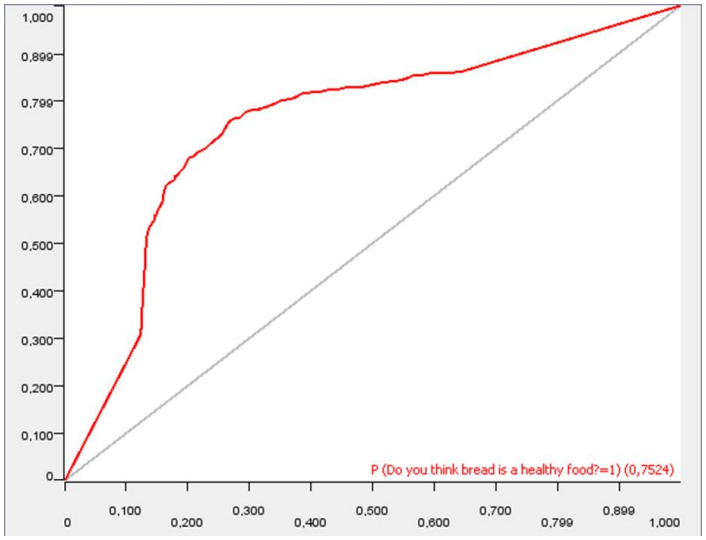



Figure 9
ROC curve for the perception of being bread healthiness with Decision Tree algorithm

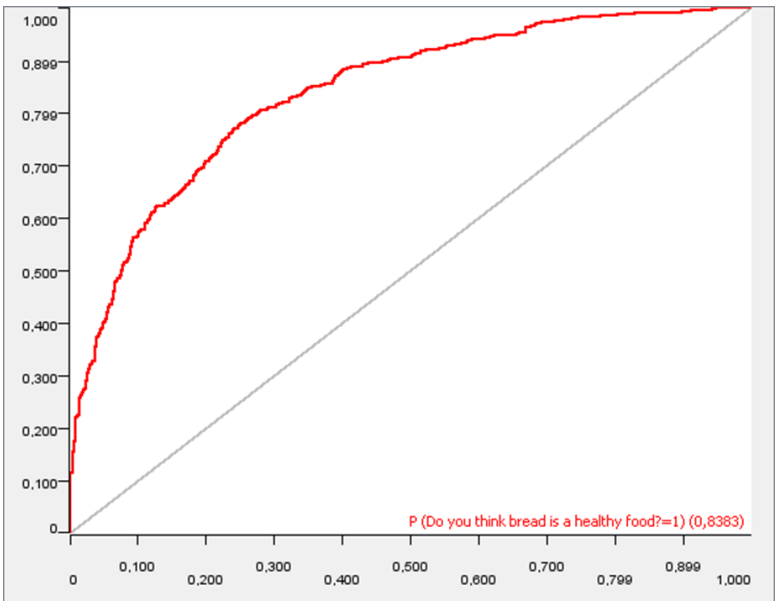



Figure 10
ROC curve for the perception of being bread healthiness with Naïve Bayes algorithm

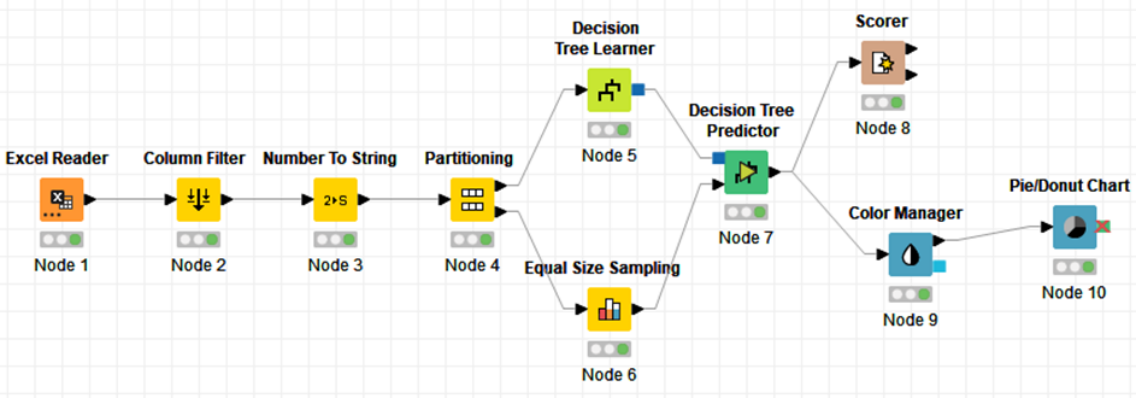



Figure 11
Workflow of Decision Tree algorithm revealing consumers' habit for eating bread per day

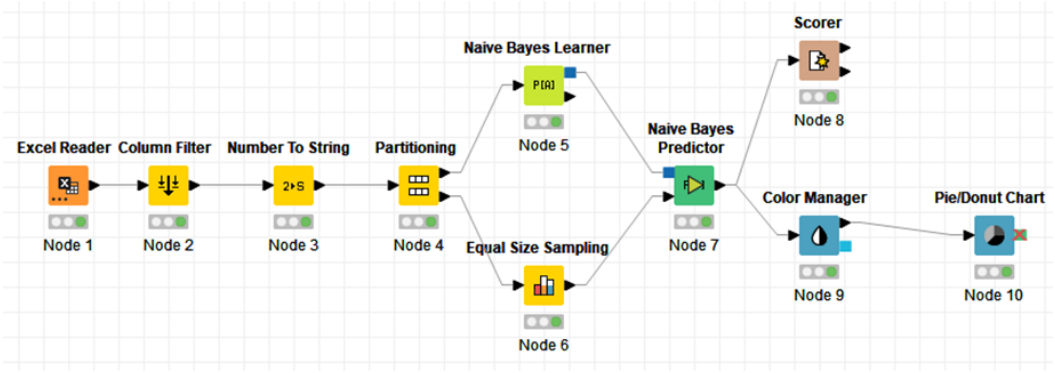



Figure 12
Workflow of Naïve Bayes algorithm representing consumers' habit for eating bread per day

The confusion matrices and performance metrics of both algorithms are represented together in Table 15 for this stage of the study. Although the performance metric values obtained from the Naive Bayes algorithm are higher than those obtained from the Decision Trees algorithm, it can still be stated that they are relatively low. A total of 181 correct predictions were made in the Decision Trees algorithm, and a total of 187 correct predictions were made in the Naive Bayes algorithm. The percentages of correct predictions made in the decision tree algorithm are 12%, 31%, 27%, 16% and 14% for the values 0, 1, 2, 3 and 4, respectively (Figure 13). In the Naive Bayes algorithm, the percentages for 0, 1, 2, 3 and 4 values are 39%, 10%, 17%, 9% and 25%, respectively (Figure 14).

Table 15
Confusion matrices and performance metrics of habit for eating bread

| Decision Tree | | Predicted value | | | | | Accuracy | Performance metrics | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | | Sensitivity | Specificity | Precision | F-score | Cohen's Kappa |
| Actual value | 0 | 49 | 24 | 10 | 3 | 0 | | 0.570 | 0.991 | 0.942 | 0.710 | |
| | 1 | 3 | 44 | 21 | 9 | 9 | | 0.512 | 0.735 | 0.326 | 0.398 | |
| | 2 | 0 | 34 | 33 | 8 | 11 | 0.421 | 0.384 | 0.765 | 0.289 | 0.330 | 0.276 |
| | 3 | 0 | 16 | 30 | 28 | 12 | | 0.326 | 0.878 | 0.400 | 0.359 | |
| | 4 | 0 | 17 | 20 | 22 | 27 | | 0.314 | 0.907 | 0.458 | 0.372 | |
| Naïve Bayes | | Predicted value | | | | | Accuracy | Performance metrics | | | | |
| | | 0 | 1 | 2 | 3 | 4 | | Sensitivity | Specificity | Precision | F-score | Cohen's Kappa |
| Actual value | 0 | 79 | 3 | 0 | 0 | 2 | | 0.940 | 0.750 | 0.485 | 0.640 | |
| | 1 | 48 | 12 | 12 | 3 | 9 | | 0.143 | 0.908 | 0.279 | 0.189 | |
| | 2 | 18 | 14 | 24 | 7 | 21 | 0.445 | 0.286 | 0.854 | 0.329 | 0.306 | 0.307 |
| | 3 | 11 | 10 | 22 | 20 | 21 | | 0.238 | 0.952 | 0.556 | 0.333 | |
| | 4 | 7 | 4 | 15 | 6 | 52 | | 0.143 | 0.842 | 0.495 | 0.550 | |

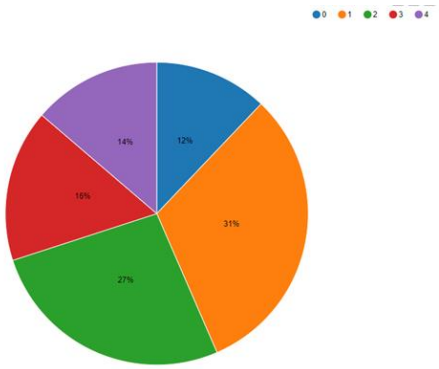



Figure 13
The prediction level of eating bread habit with the Decision Tree algorithm

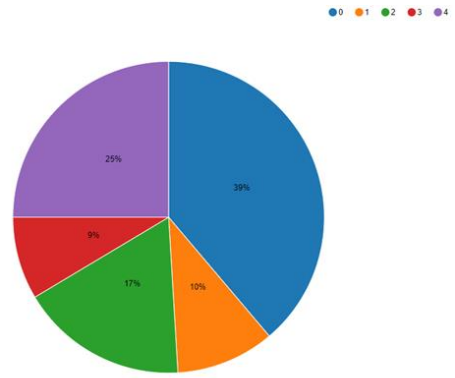



Figure 14
The prediction level of eating bread habit with the Naïve Bayes algorithm

*Conclusion*

This study is conducted at the national level with a large sample size of consumers. With this structure, it can be stated that the study is unique, and the results obtained are suitable for generalization. Although bread is sacred to Turkish society, it still constitutes an important component of Turkish food culture. Although bread consumption in Turkey seems to be high compared to many western countries, individuals are trying to reduce their bread consumption due to obesity and various health problems, which show a significant prevalence rate. While the results obtained from this study support the inferences, the characteristics such as bread consumption, taste, aroma, appearance, nutritiveness, and low calories are tried to be reduced by the influence of factors such as income level and living conditions, gender, are considered. Bread consumption preferences are directed towards whole wheat bread and rye bread. Descriptive statistics and correlation analysis can reveal the change in bread consumption preferences seen in society in recent years. The interaction between consumer attitudes and perceptions and socio-demographic characteristics that affect bread consumption preferences is evident. Key and structural concepts such as healthy life, high-quality bread consumption, low calories, changing living and working conditions, and women's participation in business life at least as much as men come to the fore. In addition, in this study, using Decision Trees and Naïve Bayes algorithms, classification approaches within the supervised data mining methods were used in the bread consumption perception and preferences of consumers.

It is focused on the attitudes, perceptions, and thoughts of consumers on whether bread is healthy food and about daily consumed bread slices. As a result of both algorithms, it is defined that the estimation results of bread being a healthy food are more consistent and valid. In future studies, it is thought that it would be appropriate to use other machine learning algorithms in bread consumption preferences by expanding and customizing the subjects and purposes.

## 4. Acknowledgements

We would like to thank the individuals who participated in this study for their participation, especially during the period of the Covid-19 epidemic.

## 5. References

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**Research Article**

# Population Development and Determination of Infestation Rate of Greenhose Tomato Pests in Karatay and Meram (Konya) Districts

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**ABSTRACT**

The study was carried out during the 2018-2019 growing season under greenhouse conditions to determine the population development and infestation rates of *Thrips*, Leafhopper species, and *Tuta absoluta* damaging greenhouse tomatoes in Karatay and Meram (Konya) districts. For this purpose, 10 greenhouses of tomato were selected from the two districts. Delta-type sexual pheromone trap, blue and yellow sticky traps were hung in each greenhouse. The traps were placed in the greenhouses alongside tomato seedlings. The pests caught in these traps were counted weekly and recorded. The infestation rate of 25 plants was selected randomly from each greenhouse and their pest infestation was examined. As a result of this study, *Thrips* species in the districts were found in the early stage of the plant in blue traps and were recorded to be 29 and7 pests per week in Karatay and Meram respectively. Leaf hooppers species emerged in yellow sticky traps during the last stages of plant phenology; and in 2018-2019, a maximum of 5-4 pests per week was determined, respectively. *Tuta absoluta*, on the other hand, had a high population at the end of the season; in 2018-2019, a maximum of 636-571 adult pests per week were caught oon the traps, respectively. In 2018-2019, whereas the infestation rate of *Thrips* and Leafhopper species were 0%, the infestation rate of *T. absoluta* was 18.66% and 18.76%, respectively.

## 1. Introduction

Tomato, an indispensable vegetable of our meals, first grown in Peru and Mexico, is a member of the family Solanaceae which originate from South and Central America. It was brought to Europe by Spanish explorers (Anonymous, 2019a).

The crop is an indispensable product in human nutrition and one of the vegetables with a wide area of use in the food sector; it is one of the most produced, consumed and traded agricultural products in the world. Turkey has risen to the top ranks in tomato production in the world with the favorable climatic conditions for tomato cultivation and the development of the tomato processing industry since the 1970s. As of 2018, China ranks first in tomato production with 56.4 million tons, while Turkey ranks fourth with a production of 12.1 million tons. In 2018, 12.150.000 tons of tomatoes were produced in Turkey, of which 8.414.920 tons were fresh consumed and 3.735.080 tons for tomato paste production (Anonymous, 2019b). In our country, Antalya is ranked first with 2.504 million tons of tomatoes, Mersin with 2.500 million tons, Muğla third with 675 thousand tons and Konya ninth with 163.856 tons of tomato production (Anonymous, 2020).

Approximately 27% of tomato production in our country is done in greenhouses. The share of total tomato production in greenhouse vegetable cultivation is 53.5%. In the Mediterranean Region, 77.6% of greenhouse tomato production takes place. Antalya meets 62.5% of this production (Anonymous, 2018).

There are many diseases and pests that cause quality and quantity losses in tomato production., The pests cause product losses up to 100% if not controlled, Chemical control with pests has many disadvantages and cannot be a solution on its own. *Thrips* species, one of these pests, belong to the family Thripidae of the order Thysanoptera. There is no extensive research on the damage caused by *Thrips* in tomato cultivation areas in

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our country. However, Eltez and Karsavuran (2006) in İzmir, Karsavuran and Gücük (2006) in Manisa, and Canbay et al. (2011) in Erzincan conducted some studies in greenhouses. Leafhoppers are stated in the family Cicadellidae of the order Hemiptera. Güçlü and Özbek (1994) in Erzurum, Karsavuran et al. (2009) in Bursa, Ahmed et al. (2016) in Konya conducted various studies on leafhoppers. *Tuta absoluta* (Meyrick), which belongs to the family Gelechiidae of the order Lepidoptera, was named after Povolny in 1994 (Barrientos et al., 1998). *Tuta absoluta*, originating from South America, is the most destructive pest of tomato. In İzmir (Kılıç, 2010), Antalya (Erler et al., 2010), Mersin (Karut et al., 2011), Konya (Ünlü, 2011; Ünlü et al., 2014; Özkan et al., 2017), in Şanlıurfa (Mamay and Yanık, 2012), Eastern Mediterranean and Southeastern Anatolia Regions (Portakaldalı et al., 2013), Southern Marmara Region (Çetin et al., 2014), Diyarbakır (Bayram and Bektaş, 2014), Uşak (Aksoy and Karaca, 2015), Western Mediterranean Region (Topuz et al., 2016), Central Anatolia Region (Erdoğan, 2016), Erzincan and Iğdır (Canbay et al., 2016) and Kahramanmaraş (Aslan et al., 2017) conducted various studies on the tomato moth. This species, which has a very high damage potential, spread in a short time and became the main pest in the field and greenhouse tomato cultivation in our country.

In this study, it was aimed to detect *Thrips*, Leafhopper species and *Tuta absoluta*, which cause damage in greenhouse tomatoes in Karatay and Meram (Konya) districts using different traps, and to determine the population development and infestation rates of these pests.

## 2. Materials and Methods

The main material of the study comprised of some pests observed in tomato greenhouses and greenhouses selected in Konya (Meram and Karatay). In the selected greenhouses, blue sticky trap was used to determine the population of *Thrips* species, yellow sticky trap to determine the population of Leafhopper species, and delta type sexual attractive pheromone traps to determine *T. absoluta* population.

In the study, three greenhouses from Karatay district and seven greenhouses from Meram district (Meram-1 and Meram-2) were selected. Studies were carried out in 10 greenhouses in both districts. The areas of the greenhouses were 500 $m^2$ and their altitude between 1010-1020 m (Table 1).

Table 1
Features of the greenhouses where the study was conducted

| Location | Trap Type | Area (m²) | Coordinates | | Altitude (m) |
|---|---|---|---|---|---|
| Karatay 1 | Pheromone - Yellow-Blue | 500 | 37°49’52”N | 32°33’40”E | 1010 |
| Karatay 2 | Pheromone - Yellow-Blue | 500 | 37°49’52”N | 32°32’00”E | 1010 |
| Karatay 3 | Pheromone - Yellow-Blue | 500 | 37°50’60”N | 32°32’53”E | 1010 |
| $Meram_1$ 1 | Pheromone - Yellow-Blue | 500 | 37°46’23”N | 32°29’00”E | 1020 |
| $Meram_1$ 2 | Pheromone - Yellow-Blue | 500 | 37°46’23”N | 32°29’20”E | 1020 |
| $Meram_1$ 3 | Pheromone - Yellow-Blue | 500 | 37°46’23”N | 32°29’40”E | 1020 |
| $Meram_2$ 1 | Pheromone - Yellow-Blue | 500 | 37°45’56”N | 32°27’39”E | 1010 |
| $Meram_2$ 2 | Pheromone - Yellow-Blue | 500 | 37°46’49”N | 32°26’54”E | 1010 |
| $Meram_2$ 3 | Pheromone - Yellow-Blue | 500 | 37°46’55”N | 32°29’42”E | 1010 |
| $Meram_2$ 4 | Pheromone - Yellow-Blue | 500 | 37°46’46”N | 32°29’45”E | 1010 |

A pheromone trap, a blue sticky trap and a yellow sticky trap were hung on each of the greenhouse. In weekly counts, all traps were checked one by one, and pests present on the traps were determined.

While tomato seedlings were planted in the greenhouses, traps were hung and a regular count was made every week. Adult insect population check-up continued until tomato harvest. The yellow and blue traps were changed every two weeks and the pheromone capsules every six weeks. The sticky portions on the traps were replaced with new ones when they lost their sticky properties. The number of pests identified on the traps were recorded as a result of weekly checks.

Visual control method was used to determine the infestation rate in tomato plants. All parts of 25 randomly selected plants were examined, the larvae or larval feeding damage of the pest was counted and these plants were accepted as contaminated. The rate of infestation count was made without discriminating fruit / leaf infestation. These steps were repeated separately for each pest.

## 3. Results and Discussion

1200 tomato seedlings were planted in each greenhouse of 500 m² in the Karatay and Meram districts of Konya. Along with the planting of tomato seedlings in the greenhouses, a pheromone trap, a blue sticky trap and a yellow sticky trap were hung. The traps were conveniently placed 20-30 cm above the tomato seedlings.

The population monitoring of the pests was carried out regularly, and the adult numbers of the pests detected in each trap were recorded. The first insect count was held from April 16$^{th}$ in 2018 to April 20$^{th}$ in 2019. Thrips species, Leafhoppers and Tomato moth were determined in the greenhouses.

### 3.1. Population Development of Pests

#### *3.1.1. Population Development of Thrips spp.*

The 2018-2019 data of the adult population devolepment in the blue sticky traps of *Thrips* species in Karatay district are given in Figure 1

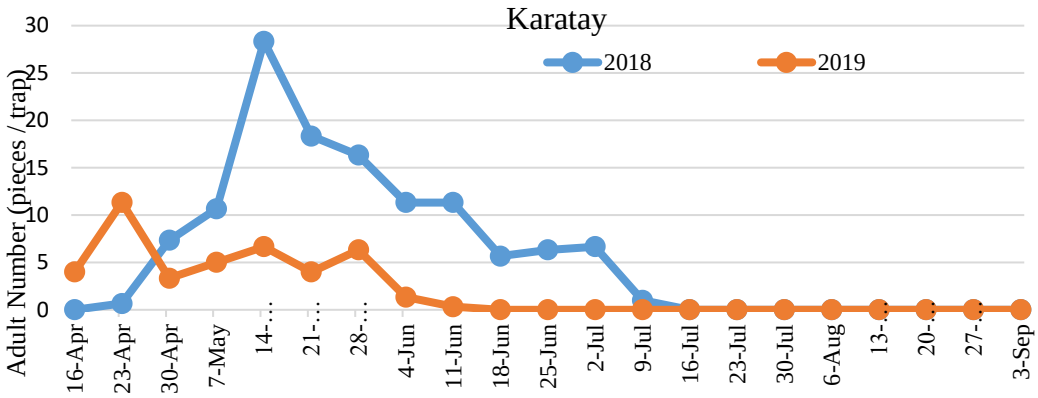


Figure 1
Population development of *Thrips* species in tomato greenhouses in Karatay in 2018 and 2019.

The first adults of *Thrips* species was seen on April 23 (2 pieces/trap) individual in Karatay district in 2018. The highest number of adults was recorded on May 14 (48 pieces/trap). *Thrips* spp. achieved 3 peaks and its population was not seen after 9 July. In 2019, the second year of the study, the first adult emergence started on April 20, and a total of 12 trapped adults were caught in three greenhouses. A total of 34 pieces/trap adults were caught on April 27, this value was determined as the highest average. The 2018-2019 data of the adult population development in the blue sticky traps of *Thrips* species in Meram-1 district are given in Figure 2.

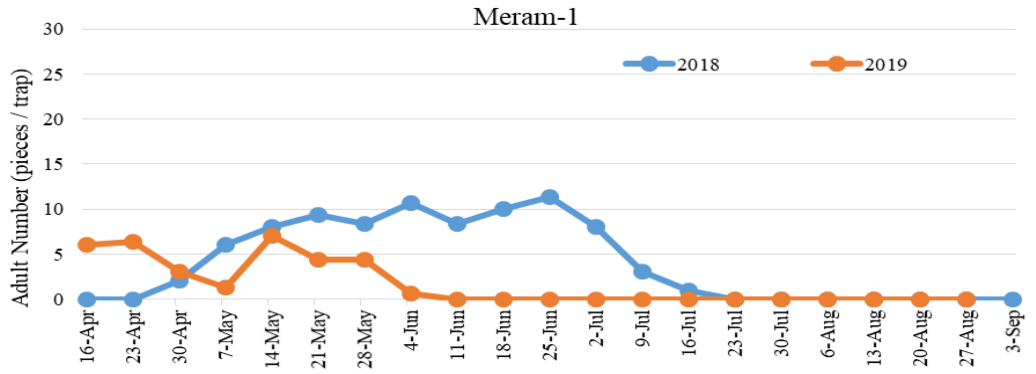


Figure 2
Population development of *Thrips* species in tomato greenhouses in Meram-1 in 2018 and 2019

At Meram-1 location, The dult individuals were seen in traps for the first time on April 30, 2018, and reached the highest level on June 25. The pest, which has achieved an average of three peaks in all three greenhouses disappeared on the traps after 16 July. In 2019, the second year of the study, the first adult emergence started on April 20, and a total of 18 pieces/trap adults individuals were caught. The highest adult was caught on May 18 (10 pieces/trap). The pest, which has 3 peaks in all greenhouses, was not seen on the traps after June 8. The 2018-2019 data of the adult population development in the blue sticky traps of *Thrips* species in Karatay district is given in Figure 3.

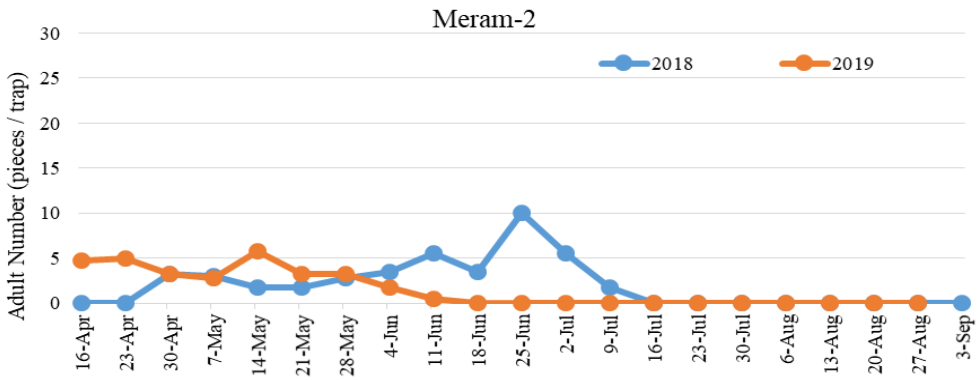


Figure 3
Population development of Thrips species in tomato greenhouses in Meram-2 in 2018 and 2019.

In the Meram-2 location, the first adults appeared in traps on April 30, 2018, and the highest value of the pest that reached three peaks was recorded on June 25 (40 pieces/trap). The pest could not be seen on the traps after 9 July. In 2019, the second year of the study, first adult was determined on April 20. It was determined that the pest that reached the highest value on May 18 (23 pieces/trap) made two peaks. The pest was not seen on the traps after 15 June.

In the study, *Thrips* species were seen only in blue traps and no leaf and fruit infestation was found. The absence of *Thrips* on the traps in late June-early July indicates that this pest is an early pest. In 2018, the highest adult was seen in the district of Karatay (48 pieces/trap) in all traps and the weekly highest value was recorded as 85 pieces/traps. In the second year of the study, a maximum of 13 pieces/traps were caught in the district of Karatay, while a total of 34 pieces/trap adults were caught weekly.

Eltez and Karsavuran (2006) determined the population of *Thrips tabaci* as 1-86 individuals/leaf in their study in the industrial tomato areas of İzmir province between 2003-2004 and recorded a value of 1-20 individuals/leaf in their study in 2005. Two weeks after planting in tomato leaves, the number of adult individuals was high and they saw a decrease in population density from the second half of July in general. In this study, it was determined that the population of *Thrips* species in all greenhouses was low, could not exceed the economic damage threshold and could not cause leaf/fruit infestation. Canbay et al. (2011) reported in their study in Erzincan that *Thrips* species exceeded the economic damage threshold in cucumber greenhouses, but not in tomato greenhouses.

### *3.1.2. Population Development of Leafhoppers*

Our study was carried out without species identification of leafhoppers. The 2018-2019 data of the adult population development in the yellow sticky traps of Leafhoppers in Karatay district are given in Figure 4.

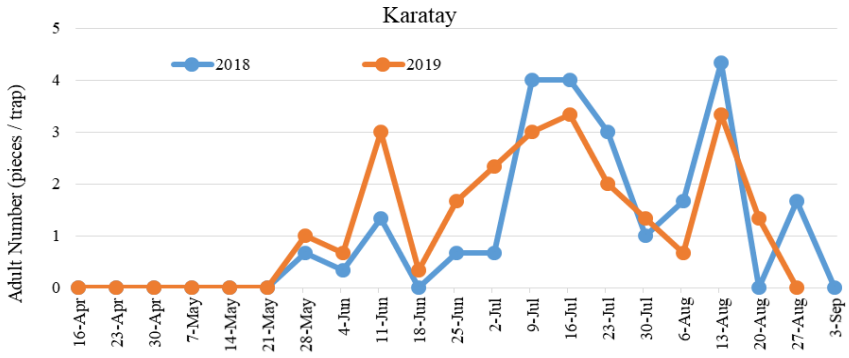


Figure 4
Population development of Leafhoppers in tomato greenhouses in Karatay in 2018 and 2019.

In the district of Karatay in 2018, leafhopper adults emerged on May 28. The highest number of adults was determined on August 13 (13 pieces/trap). Although it was not seen very intensely, the pest's presence on the traps continued until the end of August. According to the data of 2019, which is the second year of the study, the pest emerged on the traps on June 1, and the total number of adults (10 pieces/trap) reached on August 17. The 2018-2019 data of the adult population development in the yellow sticky traps of Leafhoppers in Meram-1 district are given in Figure 5.

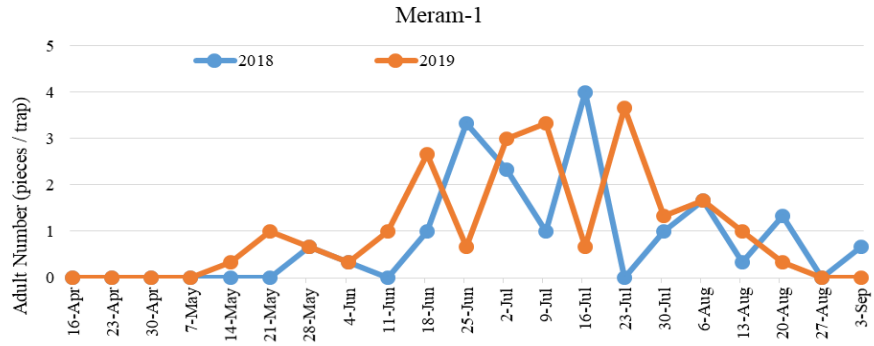


Figure 5
Population development of Leafhoppers in tomato greenhouses in Meram-1 in 2018 and 2019.

In the Meram-1 location, on May 28, 2018, leafhoppers adults were first seen in yellow sticky traps. The average highest number of adults was reached on July 16 (12 pieces/trap). Although it was rarely seen until the end of the greenhouse production season, its presence in

traps continued. The first adult emergence of the leafhoppers in 2019 started on May 18th. The highest number of adults occured on July 27 (11 pieces/trap). The 2018-2019 data of the adult population development in the yellow sticky traps of Leafhoppers in Meram-2 district are given in Figure 6.

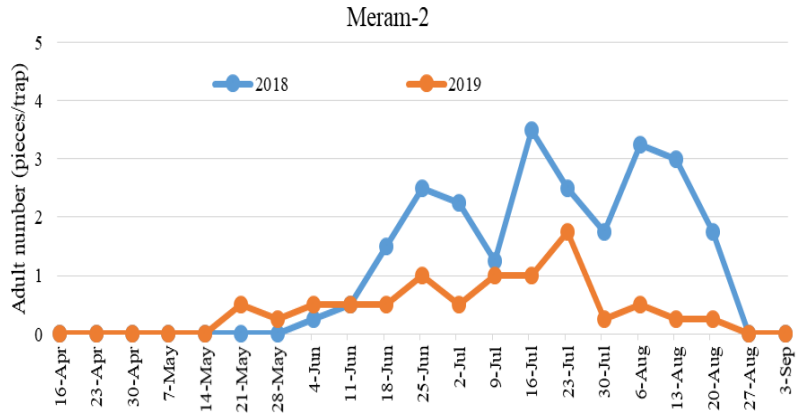


Figure 6
Population development of Leafhoppers in tomato greenhouses in Meram-2 in 2018 and 2019.

In the Meram-2 location in 2018, first adult Leafhoppers was caught on June 4. The total number of adults reached (the highest number) was 14 pieces/trap on July 16. In 2019, the second year of the study, the first adult emergence was recorded on 25 May. The highest total number of adults was reached on July 27 (7 pieces/trap).

The Leafhoppers were seen only in yellow sticky traps and no damage was observed on the plant. In 2018, the weekly maximum number of adults was recorded as 9 pieces/trap, and the total weekly highest value was recorded as 14 pieces/traps. In 2019, the weekly maximum number of adults was recorded as 6 pieces/traps, and the total weekly highest value was recorded as 11 pieces/traps. The pest, which started to be seen on the traps at the end of May, continued to exist until the end of August. The specimens encountered on the traps in both years could not reach the high population value for Konya province.

Ahmed et al. (2016), in their study in Konya (Meram) in 2011, reported that the highest number reached by *Zyginidia sohrab* was 153 adults/100 sweepnet in tomato, and 51 adults/100 sweepnet in *Empoasca decipiens*.

### *3.1.3. Population Development of Tuta absulata*

The 2018-2019 data of the adult population development in the pheromone traps of *Tuta absoluta* in Karatay district are given in Figure 7.

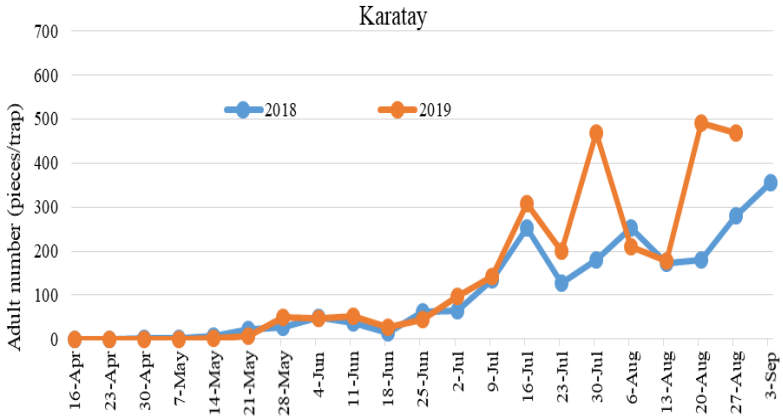


Figure 7
Population development of *Tuta absoluta* in tomato greenhouses in Karatay in 2018 and 2019.

In 2018, Tomato moth was first seen on the traps in Karatay district on April 30. The population of the pest, which reached an average of four peaks in the greenhouses, increased in July-August. The highest number of adults (475 pieces/trap) was recorded at the end of the greenhouse production season. On the traps in three unit greenhouses in Karatay district, the weekly average maximum value was 356 pieces/trap. The pest's presence on the traps ended with the uprooting of the tomato plants. In 2019, the second year of the study, the pest appeared on the traps on May 4. The highest number of adults reached on August 24 (612 pieces/trap). The weekly average highest value was 490 pieces/trap (Figure 7).

The 2018-2019 data of the adult population development in the pheromone traps of *T. absoluta* in Meram-1 district are given in Figure 8.

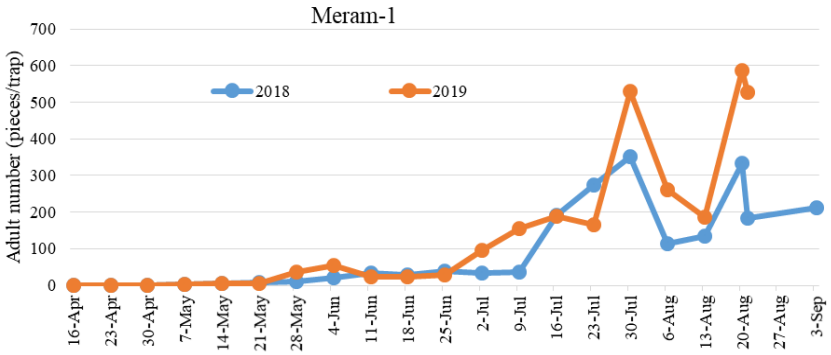


Figure 8
Population development of *Tuta absoluta* in tomato greenhouses in Meram-1 in 2018 and 2019.

According to the data of 2018, the adults of the tomato moth started to be seen on the traps on April 30 at Meram-1 location. Populations of the pest that form 3 peaks in the greenhouses in this region increased in July and August. The highest number of adults (639 pieces/trap) was reached at the end of the greenhouse production season, and the weekly average maximum value was 352 pieces/trap in each of the three greenhouses where the study was conducted. The counts ended with the removal of the tomato plants. The counts ended with the process of removing the tomato plants from the greenhouse. In 2019, the second year of the study, adult emergence started on April 20. The highest number of adults reached 621 pieces/trap on 24 August. The weekly average highest value was recorded as 587 pieces/trap. The 2018-2019 data of the adult population development in the pheromone traps of *T. absoluta* in Meram-2 district are given in Figure 9.

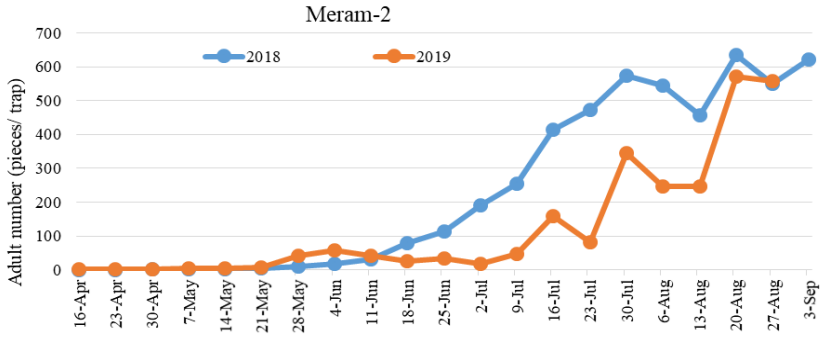


Figure 9
Population development of *Tuta absoluta* in tomato greenhouses in Meram-2 in 2018 and 2019.

In 2018, the adults of the tomato moth were seen on the traps at the Meram-2 location on April 30. The pest, which increased in population in August, formed three peaks. The highest number of adults was reached on 20 August (721 pieces/trap). The weekly average highest value was recorded as 636 pieces/trap. The pest's presence in greenhouses ended with tomato harvesting on September 3. In 2019, the second year of the study, the first adult emergence started on April 20. The highest number was reached on August 24 (628 pieces/trap). The weekly average highest value was 571 pieces/trap.

Since there was no heating system in all greenhouses in Konya, tomato production season covers the beginning of April and the end of August. *Tuta absoluta* began to appear oon the traps two weeks after the traps were set (towards the end of April). While damaging the leaves towards the end of June, the damage to the fruit was found towards the end of August. Due to the harvesting of the crop from the greenhouses in Konya at the end of August, the pest's existence ends in August. It was observed that it is active for 4 months in the greenhouses. In the weekly counts in 2018, a total of 1069 (pieces/trap) adults were caught oon the traps in Karatay district, 1057 (piece/trap) adults in Meram-1 location and 2544 (pieces/trap) adults in Meram-2 locations. It was observed that the presence of the pest, which formed three peaks, oon the traps reached its highest levels at the end of August. In the second year of the study, a total of 1472 (pieces/trap) adults were caught on the traps in Karatay district, 1761 (pieces/trap) adults in Meram-1 location and 2284 (pieces/trap) adults in Meram-2 locations.

Mamay and Yanık (2012) stated that the first adult emergence of *T. absoluta* in the open field occurred in the first half of May, and that it could give four offspring in nature by forming four peaks in July, August, September and October. They also reported that their flights continued actively for seven months until November. Özkan (2012) stated that he detected the presence of pests in greenhouses in Konya, that the pest was densely found in tomato greenhouses, damaged the leaves and fruits of the plants, and formed 3-4 peaks during tomato production season.

3.2. Infestation Rate of Pests

In the study, since the population of *Thrips* species in all greenhouses was not very high (48 pieces/trap), no contamination was found in tomato fruit and leaves. The infestation rate has been recorded as 0%., The population of the leafhopper species was also low (9 pieces/trap), and the infestation rate was recorded as 0%. The infestation rate of *T. absoluta* in tomato greenhouses was determined as 16.92%, 17.53% and 21.53% at Karatay, Meram-1 and Meram-2 locations, respectively in 2018. The least infestation rate was in the district of Karatay. The reason for this is that the tomato plants in the greenhouse where the trap was located were affected with virus disease towards the end of the season, thus the leaves were dry and the fruit yield was very low. In 2019, the second year of the study, the rate of infestation was determined as 16.30%, 18.76 and 21.23% in Karatay, Meram-1 and Meram-2 locations, respectively. The data on the weekly infestation rate of the tomato leaves and fruits of *T. absoluta* for 2018 and 2019 are given in Table 2.

Table 2
The rate of infestation of *Tuta absoluta* in tomato greenhouses in 2018 and 2019 (%)

| | Karatay | | Meram-1 | | Meram-2 | |
|---|---|---|---|---|---|---|
| Date | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| 11 June | 4.00 | 0.00 | 8.00 | 4.00 | 4.00 | 4.00 |
| 18 June | 12.00 | 8.00 | 4.00 | 12.00 | 8.00 | 12.00 |
| 25 June | 8.00 | 4.00 | 4.00 | 8.00 | 12.00 | 8.00 |
| 2 July | 16.00 | 8.00 | 12.00 | 16.00 | 20.00 | 12.00 |
| 9 July | 12.00 | 16.00 | 16.00 | 8.00 | 12.00 | 8.00 |
| 16 July | 24.00 | 4.00 | 8.00 | 12.00 | 16.00 | 16.00 |
| 23 July | 20.00 | 12.00 | 16.00 | 8.00 | 12.00 | 8.00 |
| 30 July | 12.00 | 16.00 | 36.00 | 20.00 | 24.00 | 24.00 |
| 6 August | 8.00 | 12.00 | 16.00 | 12.00 | 28.00 | 16.00 |
| 13 August | 16.00 | 24.00 | 24.00 | 32.00 | 32.00 | 28.00 |
| 20 August | 24.00 | 32.00 | 28.00 | 28.00 | 36.00 | 36.00 |
| 27 August | 28.00 | 40.00 | 24.00 | 44.00 | 40.00 | 56.00 |
| 3 September | 36.00 | 36.00 | 32.00 | 40.00 | 36.00 | 48.00 |
| Average | 16.92 | 16.30 | 17.53 | 18.76 | 21.53 | 21.23 |

## 4. Conclusions and Recommendations

As a result of the study, it was observed that there were *Thrips* spp. in blue sticky traps hanged in all greenhouses, Leafhoppers in yellow sticky traps, and Tomato moth in pheromone traps. Although *Thrips* and Leafhoppers constitute a population value below Economic Tresholds, their presence in greenhouses was detected in both years of the study. These pests, seen only on the traps, were not found on the plant.

Although *T. absoluta* started out towards the end of April, it was observed that it reached a high population in July-August. The pest's formation of 2-3 peaks showed that it gave 2-3 offspring during the greenhouse production season. The pest, encountered in the leaf galleries in June, passes to the fruits in August and ends on the traps with tomato harvesting in the greenhouses. In the weekly controls, in 2018, a maximum of 721 adults (pieces/traps) were caught, and a maximum of 2544 adults (pieces/ raps) were caught weekly. In 2019, the second year of the study, the weekly controls were recorded as a maximum of 628 pieces/traps and a maximum of 2284 adults (pieces/traps) were caught weekly. The highest values were recorded at the end of August.

The average infestation rate was 18.66% and 18.76% in 2018 and 2019, respectively. The study was conducted without discriminating the leaf and fruit infestation of *T. absoluta*. Karut et al. (2011) recorded the highest rate of shoot fruit per plant caused by *T. absoluta* larvae as 38.4%. Özkan (2012) reported the highest infestation rate for tomato leaves as 80% and for fruits as 25%. Mamay and Yanık (2012) determined that 100% of tomato plants in the fields were infestated. Aksoy and Karaca (2015) reported that the infestation increased above 50% in leaves and 25% in fruits in closed areas and reached a significant level of 12% in leaves and 8% in fruit in open areas. In our study, it is thought that the reason for the low infestation rate is that the producers regularly apply chemical control methods in addition to the traps; give importance to cultural struggle methods and the removal of tomato plants at the end of August. In addition, it has been observed that biotechnical pest control can be done more easily in greenhouse conditions. It has been determined that this pest, which feeds on all the above-ground parts of the tomato plant, can cause product loss up to 100% if it is not controlled.

In addition to causing quality losses in tomatoes in a high population, it is recommended to keep pests that are virus carriers under biotechnical methods and not to resort to chemical control. It is recommended to install pheromone traps in greenhouses cultivated with tomato seedlings to control the population of *T. absoluta* and to decide the time and method of struggle. On the other hand, Tomato moth traps used by producers in the second year of the study in the greenhouses excluded from the study also played a role in reducing the population.

It has been observed that prioritizing cultural struggle operations supported with biotechnical struggle in the control against *T. absoluta* has a very important role in the fight against pests. It is recommended that chemical control is done according to the adult number on the traps. It is recommended that chemical control, which threatens nature and people, has a detrimental effect on pests as well as beneficial species, should always be considered as the last step and prioritize other methods of management.

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# Determination of Agricultural Characteristics of Local Potato Breeding Lines

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**ABSTRACT**

This study aimed to determine the potato breeding lines that show superior agricultural characteristics and can be variety candidates by selection. The experiment was arranged in a randomized complete blocks design in both years with four replications. In the study, 20 potato breeding lines developed by Selcuk University, Faculty of Agriculture, Department of Field Crops and 18 registered varieties as plant material were used in the first year. In the second year, the study continued with 7 breeding lines and 8 registered varieties that were at the end of the first year. In the study; emergence period (days), maturation time (1-9 scale), plant growth type (3-7 scale), plant height (cm), number of main stems per plant (pieces), number of tubers per hill (pieces), average tuber weight (g), tuber yield per hill (g), total, large, medium small, discarded tuber yields (kg da$^{-1}$), number of eyes per tuber (piece), tuber shape (1-9 scale) were examined. In all field parameters, the differences between genotype in 2019 and between location, genotype and location x genotype interactions in 2020 were statistically significant. The total tuber yield varied between 2001.2 kg da$^{-1}$ and 6029.8 kg da$^{-1}$ in 2019. For the year 2020; It was determined between 2766.4 kg da$^{-1}$ and 5598.2 kg da$^{-1}$. Among the potato breeding lines in both years, ELAF11 (6029.8 kg da$^{-1}$ in 2019; 4939.9 kg da$^{-1}$ as genotype average in 2020) was the leading line in terms of total tuber yield per decare. Overall, the potato breeding lines that gave the best results differed. ELAF11 and ELAF10 lines were determined as potato breeding lines with high tuber yield.

## 1. Introduction

Extensive usage area of potato has caused it to become an essential food in many fields of the world. Its usage area includes frozen food products (French fry, potato chips, mashed potatoes), flour, alcohol, starch etc. Its greens and discarded tubers are important for animal feeding (Caliskan et al. 2010).

According to 2019 data, approximately 370.436 million tons potatoes are produced in 17.3 million hectares of field area worldwide. When it is looked at the potato production countries, China is in the first position with 91.8 million tones and it is followed by India (50.2 million tone), Russia (22.1 million tons), Ukraine (20.3 million tons), United States of America (19.2 million tons) and other countries. Turkey is in the 14th position with 5.0 million tons in the list of potato production around the world (Anonymous, 2021a).

The potato production is mainly done in the cities such as Nigde (≅ 689 thousand tons), Konya (≅ 638 thousand tons), Afyon (≅ 551 thousand tons), Kayseri (≅ 540 thousand tons), İzmir (≅ 435 thousand tons), Nevşehir (≅ 289 thousand tons), Aksaray (≅ 250 thousand tons), Adana (≅ 211 thousand tons), Sivas (≅ 192 thousand tons), Bolu (≅ 137 thousand tons) in our country (Anonymous, 2021a).

Although potato production as a primary or second product is possible because of our country's climate, European countries and North countries such as Russia and Ukraine continue to export early potatoes successfully. Our country's early potato export rate of 1 % or 2 % seems insufficient compared with Egypt, Israel, or South Cyprus. Turkey's import rate was 97.348 tons, and the export rate was 288.793 tons in 2019.Potato seeds have been imported such as mainly Holland, Germany, Scotland, Canada, France, Ireland and USA. (Caliskan et al. 2010; Gunel et al. 2010; Anonymous, 2021a). While industrial potato production is over 50 % globally, Turkey's industrial potato production rate is approximately 11 % and is in the growth trend (Caliskan, 2014).

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Setbacks in the procurement of certified seeds have caused the farmers to use the crops from last year. Tubers are not pure from diseases; it causes diseases and viruses to spread, consequently, yield decreases critically (Caliskan et al. 2011).

Considering the potato is the most used plant as a seed for unit area, seeds are the biggest input in the cost sheet. Therefore, good and qualified seed usage is essential for a healthy production (Caliskan et al. 2015). During the variety development process, it is necessary to activate the transfer program of local potato varieties that are brought into our country's agriculture to our farmers, found the seed production system, increase the studies for breeding of varieties that have a high special adaption ability other than varieties that have a high general adaption ability (Caliskan et al. 2010, Ozturk and Polat 2017). In recent years, potato variety development studies have been accelerated. In conclusion, there are 191 registered potato varieties today (Anonymous, 2021b).

This study aimed to evaluate the field performance of some trade registered potato varieties and promising variety lines selected as 5th field generation in the breeding program by Associate Professor Rahim Ada and determine the lines that can be variety candidates by making an intended selection.

## 2. Materials and Methods

This study was conducted in Konya for the first year and both in Konya and Karaman-Akçaşehir locations for the second year of 2019-2020 vegetation periods. In Konya location, field studies were conducted at Selcuk University Faculty of Agriculture Abdulkadir Akcin Trial Field and Karaman-Akcasehir farmer field, as extending to the time period of April and September.

Soil samples were collected from experimental areas at 0-30 cm depth before basal fertilizer application. The all samples were analyzed by Selcuk University, Agriculture Faculty, Department of Soil Science and Plant Nutrition and results are presented in Table 1. The all soil samples show a neutral reaction and have a salt character, a little organic matter content.

Soil samples taken from Konya location in 2019, have included high amount of extractable K, Mg, enough amount of Ca, Mn, Cu, Zn, B and an average amount of N, P, Fe. Soil samples that were taken from Konya location in 2020 included high amount of extractable Mg, Cu, enough amount of Ca, Zn, an average amount of P, Mg, Fe and insufficient amount of N, B. These values of soil samples that were taken from Akcasehir location in 2020, have been determined as high amount of extractable Ca, K, Mg, enough amount of P, Mn, Cu, Zn and insufficient amount of N, B (Namli, 2012; Demir, 2021; Anonymous, 2021c).

Table 1
Some physcial and chemical characteristics of the 0-30 cm soil layer of the experimental sites

| Soil parameters | Konya 2019 | Konya 2020 | Karaman 2020 |
|---|---|---|---|
| pH (1:2.5 s:w) | 7.46 | 7.43 | 7.11 |
| EC (µS $cm^{-1}$; 1:5 s:w) | 208.4 | 158.8 | 269 |
| Organic matter (%) | 1.08 | 1.37 | 1.76 |
| Inorganic nitrogen (%) | 20.9 | 36.1 | 10.0 |
| $CaCO_3$ (%) | 50.8 | 36.2 | 38.5 |
| Textural class | Loam | Loam | Clay-Loam |
| P (mg $kg^{-1}$) | 9.33 | 14 | 25.3 |
| K (mg $kg^{-1}$) | 798 | 416 | 630 |
| Ca (mg $kg^{-1}$) | 3221 | 3811 | 3398 |
| Mg (mg $kg^{-1}$) | 565 | 178 | 456 |
| Na (mg $kg^{-1}$) | 453 | 108 | 267 |
| B (mg $kg^{-1}$) | 1.45 | 0.05 | 0.05 |
| Cu (mg $kg^{-1}$) | 1.19 | 1.17 | 1.15 |
| Fe (mg $kg^{-1}$) | 2.49 | 3.99 | 2.65 |
| Zn (mg $kg^{-1}$) | 3.42 | 1.57 | 1.61 |
| Mn (mg $kg^{-1}$) | 5.17 | 8.82 | 6.44 |

The monthly climatic data were obtained from Konya Meteorology Services General Directorate. The mean values of climatic data are given in Table 2. Considering the average temperature values, Karaman location's value was determined as higher at 20.2 C° than Konya location's (19.9 C°). According to total precipitation values, Konya location's value (110.9 mm) was determined as higher than Karaman location's (73.2 mm). Considering relative humidity values, Konya location's value (45.2 %) was determined as higher than Karaman (44.3 %) (Table 2).

In the first year of the study 20 promising potato lines and 18 standard potato lines developed by Associate Professor Rahim ADA, were used. In the second year, the performances of 7 promising potato lines and 8 standard potato lines that were selected among the first-year lines were evaluated in different field conditions. The breeding lines were selected as crossbreed seeds developeded to the 5th field generation by selection. The information about these lines and varieties is shown in Table 3.

The study was conducted according to "Randomized Complete Blocks Design" with four replications between 2019 and 2020. Field was plowed with disc harrow and packer; seedbed was prepared in the spring of both first and second years.

In 2019, planting was done manually in the plant beds that were determined by markers as 70 cm x 30 cm (row spacing – intra-row) on 30th April 2019. In 2020, experiments were done by potato planting machine on 20th April 2020 at Konya and on 22nd April 2020 at Karaman. In 2019 experiments, each parcel was organized as 3 meters long and in 2020 experiments, each parcel was organized as 6 meters long by making 2 rows for each genotype.

Seed tubers preserved in suitable conditions were prepared for planting by disinfecting with imidacloprid active substance herbal medicine. The study used 15+15+15 N-P-K for 100 kg $da^{-1}$ bottom fertilizer before planting.In the growing period, 18+18+18 N-P-K for 20

kg da$^{-1}$ easy soluble composite fertilizer, 30 kg da$^{-1}$ ammonium nitrate and 15 kg da$^{-1}$ potassium sulfate fertilizer was used for the surface fertilizing (Bulbul, 2018).

After planting, Defi Maxx, which consists of 800 g l$^{-1}$ prosulfocarb + 80 g l$^{-1}$ metribuzin as the active substance, was used on all the soil surfaces by an herbal medicine pump as a care operation. After the plants were grown taller than 5-10 cm, weeding was done to struggle with weeds. The weeding operation was repeated after 15-20 days. Irrigation was done as drip irrigation regularly every 5 or 7 days. In 2019, the earthing-up operation was repeated manually in the growing and second development processes using a spade. In 2020, earthing up operation was done in every two locations by machine. Fungicidal, insecticide, and foliar fertilizers were used according to the needs. On 23rd September 2019, harvest was done manually when the plants became ready to be harvested. In 2020, potatoes were harvested on 24th September at Konya and on 28th September at Karaman by a potato raising machine..

Table 2
Monthly rainfall, temperature and relative humidity during the growing period of 2019 and 2020*

| Months-Konya | Mean Temperature (ºC) | | | Rainfall (mm) | | | Relative humidity (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Long-term | 2019 | 2020 | Long-term | 2019 | 2020 | Long-term | 2019 | 2020 |
| April | 10.9 | 9.5 | 10.8 | 33.2 | 44.8 | 35.3 | 58.4 | 64.8 | 59.5 |
| May | 15.7 | 17.8 | 15.9 | 39.2 | 6.8 | 43.5 | 56.6 | 46.0 | 53.6 |
| June | 20.4 | 21.6 | 20.3 | 26.0 | 62.8 | 23.9 | 47.4 | 51.1 | 47.9 |
| July | 24.1 | 22.8 | 25.5 | 6.0 | 19.6 | 0.9 | 36.6 | 42.3 | 36.4 |
| August | 23.2 | 23.3 | 24.2 | 6.7 | 8.4 | 0.4 | 39.8 | 43.2 | 31.4 |
| September | 19.2 | 19.5 | 22.6 | 17.0 | 6.6 | 6.9 | 44.4 | 42.9 | 42.6 |
| Mean | 22.1 | 19.1 | 19.9 | - | - | - | 47.2 | 48.4 | 45.2 |
| Total | - | - | - | 128.1 | 149 | 110.9 | - | - | - |

| Months-Karaman | Mean Temperature (ºC) | | Rainfall (mm) | | Relative humidity (%) | |
|---|---|---|---|---|---|---|
| | Long-term | 2020 | Long-term | 2020 | Long-term | 2020 |
| April | 11.5 | 11.7 | 36.7 | 28.2 | 58.2 | 56.5 |
| May | 16.1 | 17.3 | 34.8 | 14.8 | 55.9 | 47.1 |
| June | 20.2 | 21.0 | 27.6 | 28.0 | 49.8 | 24.5 |
| July | 23.4 | 25.1 | 0.9 | 0.0 | 43.6 | 5.3 |
| August | 23.0 | 23.3 | 3.9 | 0.0 | 44.5 | 6.7 |
| September | 18.8 | 22.8 | 7.4 | 2.2 | 49.4 | 8.8 |
| Mean | 18.8 | 20.2 | - | - | 50.2 | 44.3 |
| Total | - | - | 116.8 | 73.2 | - | - |

*: Climate data provided from Konya Meteorology Services General Directorate

Table 3
Information on potato varieties and breeding lines used in the study

| Varieties | Usage | Varieties | Usage | Lines | Usage | Lines | Usage |
|---|---|---|---|---|---|---|---|
| VR 808 | Chips | Marabel | Cooking | AFAG-C | Chips | ELAF-10 | Cooking |
| Brooke | Chips | Agata | Cooking | HEAF-5 | Chips | ELAF-11 | Cooking |
| Doruk | Chips | Madeleine | Cooking | T7LA-8 | French fry | T3AG-14 | Cooking |
| Russet Burbank (R.B.) | French fry | Melody | Cooking | PA-9 | French fry | T1AG-14 | Cooking |
| Lady Olimpia (L.O.) | French fry | Zirve | Cooking | AFLA-9 | French fry | T2AG-13 | Cooking |
| Innovator | French fry | Çağlı | Cooking | AFLA-20 | French fry | T3PO-13 | Cooking |
| Kutup | French fry | Leventbey | Cooking | AFHE-11 | French fry | T3LA-8 | Cooking |
| Agria | Cooking-Chips | Muratbey | Cooking | MK-2 | Cooking | PAG-5 | Cooking |
| Jelly | Cooking-Chips | | | AFK-3 | Cooking | AFBR-4 | Cooking |
| Challenger | Cooking-Chips | | | GAF-4 | Cooking | AFAG-12 | Cooking |

In the study, phenological qualities such as emergence period (day – the time when 50% of seed tubers come to the surface), maturation time (1-9 scale), plant growing type (3-7 scale) (Anonymous, 2001). plant height (cm), number of main stems plant$^{-1}$, number of tubers hill$^{-1}$, tuber yield hill$^{-1}$ (g) that became ready to be harvested were evaluated by covering all the plants for each parcel (Bulbul,2018; Ozyildirim, 2014).

Moreover, average tuber weights (g), average number of eyes tuber$^{-1}$, total tuber yield per decare (kg) and tuber yields per decare that present total tuber yields according to tuber sizes (kg) were determined. These were classified as large (tubers that are stayed on 5.0 cm diameter sieve), medium (tubers that aren't stayed on 5.0 diameter sieve but stayed on 3.5 cm diameter sieve), small (tubers that aren't stayed on 3.5 cm diameter sieve but stayed on 2.8 cm diameter sieve), discarded (tubers that aren't stayed on 2.8 cm diameter sieve) tuber yields (kg). After the harvest, tuber shapes (1-9 scale) were determined by measuring random 5 tubers taken from each parcel according to the formula below (Gunel, 1976; Karan, 2013).

Formula: tuber shape = 100 x [tuber height (mm) / tuber width (mm)].

The data were analyzed using technique of analysis of variance (JUMP) and treatment means were separated by Least Significant Differences (LSD) at 1 % probability level by using MSTAT-C as described by Nissen (1989).

## 3. Results and Discussion

The variance sources and their statistical significance were shown in Table 4 and 5 for the phenological features, yield and yield components. Data of variance analysis in Table 4 showed that the genotypes' effect on all parameters was statistically significant at 1 % probability level.

According to emergence period values in 2019 year, the highest average emergence duration value was recorded in line T3LA8 (33.3) and the lowest average emergence duration value was recorded invariety Brooke (19.5) and variety Agata (19.8) and classified the same group (Table 6). According to 2020 growing season, in terms of genotype, variety Doruk was in the first group (36.0), variety Brooke (19.3) and line ELAF10 (19.8) classified in the last group (Table 7). Yildirim and Yildirim (2002) reported that emergence duration of tubers was affected by directly or indirectly many factors. These factors can be listed as planting depth, soil content, soil temperature and moisture saturation, and genetic structure of the variety. In addition, Kara at al. (2002) reported that the physiological age of the tuber also directly affected the emergence duration. As the tubers aged physiologically, the number of shoots increased and created direct early emergence. Differences in emergence durations of genotype might be due to these reasons. Previous studies have shown that the there is a close relationship between physiological age and emergence time (Coleman and McInerney, 1997; Coleman and Coleman, 2000; Kammoun et al., 2020). The dormancy period and the earliness of the varieties also affect the emergence period. The earliest emergence duration value was recorded in the very early variety Agata.

Data recorded in plant height values revealed that the response to the years, locations, location x genotype interactions varied according to the genotypes. While the highest plant height value was recorded at line T2AG13 (85.8) in the first growing season, line ELAF11 in terms of genotype (113.9) was the highest value in second growth season. Although plant height is a variety trait, it is also affected by environmental factors such as plant density, day length, temperature, relative humidity, soil content, humidity, and nitrogen content (Caliskan and Incekara, 1980; Gunel et al., 1991; Yilmaz and Tugay, 1999). On the other hand, main maintenance practices such as irrigation also affect plant heights closely (Darabad, 2014). Late varieties are taller than early varieties and it is known that leaf area indexes increase in parallel with this (Manrique et al., 1990; Yilmaz and Tugay, 1999). The Agata variety, which was in the early group, was detected with the lowest plant height value of 45.9 cm in 2019 (Table 6).

As the trial average, the number of main stems was recorded as 4.5 per plant in 2019. The highest number of main stems was observed as 7.0 piece/plant in MK2 line, and the least number of main stems was determined in T2AG13 line with 2.2 piece/plant. 12 of these lines were below the trial average in terms of main stem number (Table 6). Looking at the data for 2020; the average number of main stems of varieties and lines was recorded as 6.1 piece/plant. In terms of main stem numbers, the location average was in the group (a) with 7.3 piece/plant in the Konya region, while the Karaman region represented the group (b) with 4.9 piece/plant. When we evaluate the genotypes; as the highest number of main stems was determined in PAG5 (8.2 piece/plant) and ELAF10 lines (8.1 piece/plant), the lowest main stem number was counted in Melody variety (4.5 piece/plant) (Table 7). Among the factors affecting the number of main stems, the number of shoots on the tuber and the size of the tuber can be listed. Because; the number of main stems is also a determinant for the estimation of tuber size and average tuber weight (Arioglu, 1990; Esendal, 1990). In addition, the temperature of the soil, nitrogen application and day length can be listed among the factors that directly affect the number of main stems (Marinus and Bodlaender, 1975; Fahem and Haverkort, 1988; Gunel and Karadogan, 1991). The data on the main stem numbers determined in this study were similar to the findings of Yilmaz and Tugay (1999), and it was recorded close to the upper limit and at higher values than Hajianfar et al. (2017) and Yilmaz et al. (2018)'s findings.

Table 4
Results of variance analysis of the growth and yield components in the experiment conducted in 2019

| Source of Variation | Means square | | | | | | |
|---|---|---|---|---|---|---|---|
| | df | Emergence period (day) | Plant height (cm) | Number of main stem plant$^{-1}$ | Number of tubers hill$^{-1}$ | Average tuber weights (g) | Tuber yield hill$^{-1}$ (g) |
| Replication | 3 | 0.11 | 0.13 | 0.01 | 0.32 | 319.29 | 16070.42 |
| Genotypes | 37 | 50.82** | 291.05** | 4.95** | 15.88** | 2960.96** | 244334.74** |
| Error | 111 | 0.23 | 0.23 | 0.01 | 0.15 | 108.87 | 10041.83 |

| Source of Variation | df | Total tuber yield da$^{-1}$ (kg) | Large tuber yield da$^{-1}$ (kg) | Medium tuber yield da$^{-1}$ (kg) | Small tuber yield da$^{-1}$ (kg) | Discarded tuber yield da$^{-1}$ (kg) | Average number of eyes tuber$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Replication | 3 | 122.65 | 636.90 | 151.14 | 80.29 | 3.55 | 0.35 |
| Genotypes | 37 | 4499073.46** | 4359197.05** | 473692.66** | 19228.42** | 3845.87** | 14.07** |
| Error | 111 | 921.06 | 561.02 | 297.37 | 64.49 | 8.67 | 0.20 |

*P < 0.05, **P < 0.01

Table 5
Results of variance analysis of the growth and yield components in the experiment conducted in 2020

| Source of Variation | | Means square | | |
|---|---|---|---|---|
| | df | Emergence period (day) | Plant height (cm) | Number of main stem plant$^{-1}$ |
| Location | 1 | 24.30** | 351.58** | 174.97** |
| Replication [L] | 6 | 2.23 | 0.18 | 0.12 |
| Genotypes | 14 | 2601.92** | 1515.23** | 10.48** |
| L x G | 14 | 206.95** | 571.12** | 13.26** |
| Error | 84 | 21.27 | 0.24 | 0.07 |
| Source of Variation | df | Number of tubers hill$^{-1}$ | Average tuber weights (g) | Tuber yield hill$^{-1}$ (g) |
| Location | 1 | 100.83** | 12683.46** | 281572.03** |
| Replication [L] | 6 | 0.08 | 42.87 | 456.04 |
| Genotypes | 14 | 44.48** | 6261.71** | 174046.62** |
| L x G | 14 | 13.40** | 2946.88** | 69967.48** |
| Error | 84 | 0.20 | 81.32 | 840.29 |
| Source of Variation | df | Total tuber yield da$^{-1}$ (kg) | Large tuber yield da$^{-1}$ (kg) | Medium tuber yield da$^{-1}$ (kg) |
| Location | 1 | 5171357.53** | 128236.33** | 3710716.36** |
| Replication [L] | 6 | 8373.49 | 6533.02 | 2794.60 |
| Genotypes | 14 | 3196588.46** | 1201170.77** | 778438.15** |
| L x G | 14 | 1285097.50** | 1836795.73** | 469782.12** |
| Error | 84 | 1540.01 | 8737.45 | 5654.37 |
| Source of Variation | df | Small tuber yield da$^{-1}$ (kg) | Discarded tuber yield da$^{-1}$ (kg) | Average number of eyes tuber$^{-1}$ |
| Location | 1 | 119088.90** | 119303.21** | 156.41** |
| Replication [L] | 6 | 1856.43 | 837.52 | 0.33 |
| Genotypes | 14 | 493104.46** | 96082.67** | 76.89** |
| L x G | 14 | 1093662.08** | 80048.37** | 8.84** |
| Error | 84 | 2046.10 | 940.35 | 0.25 |

*P < 0.05, **P < 0.01

According to 2019 data; the average number of tubers per hill of the genotypes examined in the study was 9.5. 9 lines and 13 standard varieties remained below this average value (Table 6). According to the data for 2020; In terms of the number of tubers per hill, the trial average was 8.7. In terms of locations, 9.6 piece/hill were determined in Konya location and 7.8 piece/hill in Karaman location. The number of tubers formed by each main stem gives the number of tubers in that hill. The increase in the number of tubers directly affects the tuber yield per hill and therefore the total tuber yield per decare. As a general expression; the number of main stems, the number of eyes per tuber and the variety characteristics that affect the number of tuber per hill (Yalcin and Tunçturk, 2018). In this study, there were differences in terms of the number of tubers per hill, both in terms of years and locations. This was because; the quality of the seed, the climate and soil conditions, the size of the seed tubers and other agronomic practices (Svensson, 1962). Although the values in this study were within Ozturk et al. (2008) and Yalcin and Tuncturk (2018)'s findings, it was found closer to the lower limit.

Table 6
Means of 2019 year emergence period (day), plant height (cm), number of main stem plant$^{-1}$, number of tubers hill$^{-1}$, average tuber weights (g), tuber yield hill$^{-1}$(g) of 38 potato genotypes evaluated under Konya location.

| Genotypes | Emergence period (day) | Plant height (cm) | Number of main stem plant$^{-1}$ | Number of tubers hill$^{-1}$ | Average tuber weights (g) | Tuber yield hill$^{-1}$ (g) |
|---|---|---|---|---|---|---|
| Agata | 19.8 s | 45.9 x | 4.5 j | 11.7 cd | 88.7 ı-l | 1035.0 d-f |
| Agria | 23.8 kl | 76.5 d | 5.7 d | 6.6 q | 138.8 a-c | 918.6 e-h |
| Brooke | 19.5 s | 62.9 m-o | 4.8 ı | 11.9 c | 110.6 d-h | 1317.2 ab |
| Challenger | 29.0 de | 60.5 s | 4.9 hı | 11.1 de | 84.9 ı-o | 942.3 e-g |
| Çağlı | 26.3 gh | 62.5 n-p | 5.1 fg | 8.1 l-p | 88.1 ı-m | 708.5 ı-m |
| Doruk | 25.8 hı | 71.1 f | 5.0 gh | 7.6 op | 120.3 c-e | 910.6 e-h |
| Innovator | 24.3 jk | 61.9 pq | 5.2 ef | 8.1 l-p | 87.7 ı-n | 710.5 ı-m |
| Jelly | 24.8 j | 60.8 rs | 3.5 pq | 7.9 n-p | 151.8 a | 1201.5 b-d |
| Kutup | 29.5 cd | 66.3 j | 4.0 m | 7.7 op | 121.3 c-e | 927 2 e-h |
| L.O. | 25.0 ıj | 56.5 v | 5.7 d | 10.2 fg | 86.7 ı-n | 882.8 f-ı |
| Leventbey | 22.3 no | 67.6 hı | 3.6 op | 7.9 n-p | 99.5 f-ı | 781.1 g-k |
| Madeleine | 20.8 pr | 57.4 tu | 3.8 n | 7.4 p | 147.1 ab | 1091.7 c-e |

Table 6 (continued)
Means of 2019 year emergence period (day), plant height (cm), number of main stem plant$^{-1}$, number of tubers hill$^{-1}$, average tuber weights (g), tuber yield hill$^{-1}$(g) of 38 potato genotypes evaluated under Konya location.

| | | | | | | |
|---|---|---|---|---|---|---|
| Marabel | 20.8 pr | 63.6 lm | 4.0 m | 8.7 ı-m | 149.1 a | 1292.4 ab |
| Melody | 25.8 hı | 66.7 ıj | 5.6 d | 13.8 a | 85.4 ı-o | 1176.7 b-d |
| Muratbey | 24.5 jk | 69.9 g | 3.5 pq | 6.1 q | 110.3 d-h | 670.3 j-m |
| R.B. | 23.3 lm | 63.8 l | 3.7 no | 6.6 q | 128.4 b-d | 849.4 f-j |
| VR808 | 24.5 jk | 52.5 w | 4.1 d | 9.4 hı | 103.7 e-ı | 962.0 e-g |
| Zirve | 27.3 f | 65.1 k | 5.6 j | 8.7 ı-m | 148.1 a | 1286.7 ab |
| AFAG12 | 30.0 c | 72.7 e | 5.3 e | 8.8 h-l | 95.9 f-j | 844.3 g-j |
| AFAG-C | 29.3 c-e | 72.3 e | 4.3 k | 9.0 h-k | 137.6 a-c | 1243.2 a-c |
| AFBR4 | 22.3 no | 69.3 g | 2.5 s | 8.0 m-p | 98.2 f-ı | 785.6 g-k |
| AFHER 11 | 32.3 b | 62.1 op | 4.3 k | 10.4 ef | 69.3 m-q | 721.4 ı-m |
| AFK3 | 21.5 op | 61.4 qr | 6.3 b | 12.3 bc | 64.6 pq | 794.7 g-k |
| AFLA20 | 22.5 mn | 64.7 k | 4.2 kl | 10.2 fg | 64.5 pq | 656.2 k-m |
| AFLA9 | 28.5 e | 63.1 l-n | 5.3 e | 8.6 j-n | 87.7 ı-n | 747.5 h-l |
| ELAF10 | 20.3 q-s | 69.5 g | 6.3 b | 14.5 a | 93.5 g-j | 1357.3 ab |
| ELAF11 | 22.5 mn | 75.7 d | 3.8 n | 12.7 b | 111.3 d-g | 1407.0 a |
| GAF4 | 25.0 ıj | 84.6 b | 4.0 m | 10.4 ef | 114.2 d-f | 1184.9 b-d |
| HEAF5 | 25.0 ıj | 61.0 rs | 3.6 op | 12.1 bc | 72.3 l-q | 874.6 f-ı |
| MK2 | 22.3 no | 58.0 t | 7.0 a | 8.0 m-p | 58.6 q | 466.9 n |
| PAG5 | 21.0 pq | 60.5 s | 3.0 r | 10.2 fg | 91.9 h-k | 931.7 e-h |
| PAG9 | 20.0 rs | 53.0 w | 4.5 j | 10.8 ef | 66.1 o-q | 713.3 ı-m |
| T1AG14 | 27.5 f | 57.0 uv | 6.1 c | 9.5 gh | 68.4 n-q | 652.0 k-n |
| T2AG13 | 29.8 cd | 85.8 a | 2.2 t | 9.4 hı | 59.4 q | 556.5 mn |
| T3AG14 | 26.8 fg | 67.6 h | 2.7 q | 8.3 k-o | 78.8 j-p | 651.9 k-n |
| T3LA8 | 33.3 a | 69.7 g | 3.4 lm | 9.2h-j | 77.4 j-p | 703.2 ı-m |
| T3PO13 | 23.8 kl | 71.3 f | 4.1 ı | 8.0 m-p | 73.1 k-q | 585.4 l-n |
| T7LA8 | 27.5 f | 82.9 c | 4.8 lm | 10.2 fg | 94.4 g-j | 958.7 e-g |
| Mean | 24.9 | 65.6 | 4.5 | 9.5 | 98.1 | 907.9 |
| Lsd genotype (0.01) | 0.89 | 0.89 | 0.19 | 0.72 | 19.34 | 185.70 |

When the average tuber weight data for 2019 was evaluated, the trial average was determined as 98.1 g. The highest average tuber weight was found in Jelly with 151.8 g, Marabel with 149.1 g and Zirve with 148.1 g and represented the same group (a). The lowest average tuber weight was recorded from the MK2 lines with 58.6 g and T2AG13 lines with 59.4 g, and 4 lines (AFAG-C, AFBR4, ELAF11, GAF4) were determined to be above the average (Table 6). Considering the average tuber weight values of 2020; as a location average, Karaman location was ahead of Konya location (111.5 g) with 132.0 g. According to the genotype averages; While AFAG-C line gave the highest value with 200.7 g, Doruk cultivar recorded the lowest value with 95.6 g (Table 7). For 2020, the differences in terms of locations are obvious. Generally, average tuber weights were found to be higher in Karaman location. Lower values were determined in Karaman location regarding tuber numbers per hill (Table 7). As the number of tubers per hill increases, the weight of a single tuber decreases (Caliskan and Arioglu, 1997). In this study, the lower number of main stems of genotypes in Karaman location compared to Konya location decreased the number of tubers per hill. Therefore, competition among plants decreased and it was thought that the few tubers formed grew more. As a result, it can be said that the average tuber weight values are higher in Karaman location (Table7).

Table 7
Means of two locations for emergence period (day), plant height (cm), number of main stem plant$^{-1}$, number of tubers hill$^{-1}$, average tuber weights (g), tuber yield hill$^{-1}$(g) of 15 potato genotypes evaluated in 2020 year.

| Genotypes | Emergence period (day) | | | Plant height (cm) | | | Number of main stem plant$^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Konya | Karaman | Mean | Konya | Karaman | Mean | Konya | Karaman | Mean |
| Agria | 27.5 g | 27.5 g | 27.5 e | 79.9 op | 75.5 q | 77.7 ı | 7.1 de | 3.4 o | 5.3 fg |
| Brooke | 19.3 l | 19.3 l | **19.3 ı** | 84.0 m | 56.4 s | 70.2 k | 5.1 k | 6.2 g-j | 5.7 de |
| Doruk | 34.5 b | 37.5 a | **36.0 a** | 101.0 h | 104.5 c | 102.7 b | 7.5 d | 4.5 m | 6.0 cd |
| Kutup | 31.5 d | 26.3 h | 28.9 d | 103.2 de | 85.0 l | 94.1 e | 7.3 de | 4.5 m | 5.9 d |
| L.O. | 28.3 fg | 28.3 fg | 28.3 d | 76.0 q | 53.5 t | **64.7 l** | 6.5 f-h | 3.3 o | 4.9 h |
| Melody | 25.5 h | 25.5 h | 25.5 f | 98.5 ı | 104.6 c | 101.5 c | 6.4 g-ı | 2.6 p | **4.5 ı** |
| R.B. | 23.5 ı | 22.0 j | 22.8 h | 101.5 gh | 88.0 k | 94.7 e | 9.3 b | 4.6 lm | 6.9 b |
| Zirve | 30.3 e | 37.3 a | 33.8 b | 82.0 n | 83.8 m | 82.9 h | 6.4 g-ı | 3.5 o | 5.0 gh |
| AFAG-C | 31.0 de | 31.0 de | 31.0 c | 85.9 l | 80.5 o | 83.2 h | 6.9 ef | 7.1 de | 7.0 b |
| AFBR4 | 28.3 fg | 28.3 fg | 28.3 d | 80.3 op | 104.1 cd | 92.2 f | 6.6 fg | 4.0 n | 5.3 fg |

Table 7 (continued)
Means of two locations for emergence period (day), plant height (cm), number of main stem plant$^{-1}$, number of tubers hill$^{-1}$, average tuber weights (g), tuber yield hill$^{-1}$(g) of 15 potato genotypes evaluated in 2020 year.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ELAF10 | 18.8 l | 20.8 k | **19.8 ı** | 102.1 fg | 101.1 h | 101.6 c | 10.1 a | 6.0 ıj | **8.1 a** |
| ELAF11 | 25.8 h | 28.5 f | 27.1 e | 125.0 a | 102.7 ef | **113.9 a** | 10.3 a | 4.2 mn | 7.2 b |
| GAF 4 | 30.5 e | 32.5 c | 31.5 c | 95.8 j | 82.0 n | 88.9 g | 5.8 j | 5.0 kl | 5.4 ef |
| PAG 5 | 22.3 j | 25.8 h | 24.0 g | 66.5 r | 79.4 p | 73.0 j | 6.1 h-j | 10.2 a | **8.2 a** |
| T7LA8 | 31.5 d | 31.5 d | 31.5 c | 82.1 n | 111.6 b | 96.9 d | 8.3 c | 4.3 mn | 6.3 c |
| Mean | **27.2 b** | **28.1 a** | **27.7** | **90.9 a** | **87.5 b** | **89.2** | **7.3 a** | **4.9 b** | **6.1** |
| Lsd $_{genotype\ (0.01)}$ = 0.66 | | | Lsd $_{genotype\ (0.01)}$ = 0.65 | | | Lsd $_{genotype\ (0.01)}$ = 0.35 | | | |
| Lsd $_{locationx\ genotype\ (0.01)}$ = 0.93 | | | Lsd $_{locationx\ genotype\ (0.01)}$ = 0.91 | | | Lsd $_{locationx\ genotype\ (0.01)}$ = 0.49 | | | |

| Genotypes | Number of tubers hill$^{-1}$ | | | Average tuber weights (g) | | | Tuber yield hill$^{-1}$ (g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Konya | Karaman | Mean | Konya | Karaman | Mean | Konya | Karaman | Mean |
| Agria | 12.3 bc | 6.5 l-n | 9.4 e | 68.2 o | 148.7 e | 108.4 fg | 831.4 k-m | 961.1 gh | 896.2 h |
| Brooke | 13.3 a | 8.3 gh | 10.8 c | 92.2 mn | 106.7 h-m | 99.5 gh | 1226.9 b | 872.6 jk | 1049.8 de |
| Doruk | 11.3 de | 13.8 a | **12.5 a** | 109.6 h-k | 81.6 no | **95.6 h** | 1230.1 b | 1122.6 cd | 1176.3 b |
| Kutup | 6.9 k-m | 9.6 f | 8.3 f | 155.5 d-e | 118.2 f-ı | 136.8 cd | 1058.1 ef | 1135.1 cd | 1096.6 c |
| L.O. | 7.8 h-j | 5.0 p | 6.4 h | 110.3 g-k | 187.8 b | 149.1 b | 858.1 kl | 938.2 hı | 898.1 h |
| Melody | 9.5 f | 7.3 ı-l | 8.4 f | 106.9 h-m | 150.6 de | 128.7 de | 1013.8 fg | 1099.2 de | 1056.5 d |
| R.B. | 7.1 j-l | 6.7 k-m | 6.9 h | 101.8 ı-m | 115.2 f-j | 108.5 fg | 720.2 op | 757.0 no | **738.6 j** |
| Zirve | 12.1 cd | 12.4 bc | **12.2 a** | 108.8 h-m | 92.6 l-n | 100.7 gh | 1306.3 a | 1143.1 cd | **1224.7 a** |
| AFAG-C | 6.1 m-o | 2.8 q | **4.5 ı** | 166.3 cd | 235.2 a | **200.7 a** | 1013.7 fg | 645.5 q | 829.6 ı |
| AFBR4 | 8.0 g-ı | 7.1 j-l | 7.5 g | 126.6 fg | 118.9 f-h | 122.8 e | 1008.0 fg | 833.3 k-m | 920.6 gh |
| ELAF10 | 13.0 ab | 7.3 ı-l | 10.2 d | 96.3 k-n | 107.5 h-m | 101.9 gh | 1251.2 b | 783.2 mn | 1017.2 e |
| ELAF11 | 12.3 bc | 10.6 e | 11.4 b | 95.9 k-n | 107.6 h-m | 101.7 gh | 1172.7 c | 1132.6 cd | 1152.7 b |
| GAF 4 | 9.4 f | 8.8 fg | 9.1 e | 109.4 h-l | 101.0 j-m | 105.2 gh | 1021.5 f | 884.9 ık | 953.2 fg |
| PAG 5 | 7.5 h-k | 5.4 op | 6.5 h | 109.7 h-k | 129.1 f | 119.4 ef | 818.1 lm | 687.5 pq | **752.8 j** |
| T7LA8 | 8.1 g-ı | 5.7 n-p | 6.9 h | 114.6 f-j | 179.6 bc | 147.1 bc | 925.0 h-j | 1005.9 fg | 965.5 f |
| Mean | **9.6 a** | **7.8 b** | **8.7** | **111.5 b** | **132.0 a** | **121.7** | **1030.3 a** | **933.4 b** | **981.9** |
| Lsd $_{genotype\ (0.01)}$ = 0.59 | | | | Lsd $_{genotype\ (0.01)}$ = 11.88 | | | Lsd $_{genotype\ (0.01)}$ = 38.20 | | |
| Lsd $_{locationx\ genotype\ (0.01)}$ = 0.83 | | | | Lsd $_{locationx\ genotype\ (0.01)}$ = 16.81 | | | Lsd $_{locationx\ genotype\ (0.01)}$ = 54.02 | | |

The trial average tuber yield per hill was calculated as 907.9 g in 2019. In addition, it was determined that the values for tuber yield per hill in the 2019 season varied between 466.9 g hill$^{-1}$ (MK2 line) and 1407.0 g/hill (ELAF11 line) (Table 6). When we examine the average tuber yield values per hill in 2020; in terms of location averages, Konya location surpassed Karaman location (933.4 g hill$^{-1}$) with 1030.3 g. According to the genotype averages; Zirve variety with 1224.7 g was recorded with the highest value, while Russet Burbank variety with 738.6 g and PAG5 line with 752.8 g shared the lowest value (Table 7). When the findings of Tuncturk (2006) were compared with the data in this study, it can be said that the data for 2019 was within the limits, and the data for 2020 was close to the lower limit. Yildirim et al. (2005) and Ozturk et al. (2008), it was seen that the data for 2020 was quite high, close to the determined limits of 2019. According to 2020 data, from Konya location to Karaman location; higher tuber yield values per hill were determined; It was determined that there were differences between the numbers in terms of year, location and genotype. It can be said that this may be because the genotypic structures of the varieties and lines are different and that they react differently to the ecological variables related to the years. It was stated in other studies that the effect of ecological conditions on yield is important (Kan and Akinerdem, 2000; Caliskan, 2001; Tuncturk, 2006).

Table 8
Means of 2019 year total tuber yield ha$^{-1}$ (kg), large tuber yield ha$^{-1}$ (kg), medium tuber yield ha$^{-1}$ (kg), small tuber yield ha$^{-1}$ (kg), discarded tuber yield ha$^{-1}$ (kg), average number of buds tuber$^{-1}$ of 38 potato genotypes evaluated under Konya location.

| Genotypes | Total tuber yield da$^{-1}$ (kg) | Large tuber yield da$^{-1}$ (kg) | Medium tuber yield da$^{-1}$ (kg) | Small tuber yield da$^{-1}$ (kg) | Discarded tuber yield da$^{-1}$ (kg) | Average number of eyes tuber$^{-1}$ |
|---|---|---|---|---|---|---|
| Agata | 4435.7 h | 2623.8 n | 1432.2 d | 296.4 a | 83.4 ef | 6.9 h-j |
| Agria | 3824.4 l | 2914.3 l | 757.7 st | 131.0 k | 21.4 s | 6.9 h-j |
| Brooke | 5017.8 d | 3945.3 e | 900.0 op | 134.5 jk | 38.1 o-q | 6.4 ı-n |
| Challenger | 3979.8 j | 1929.8 s | 1681.0 a | 300.0 a | 69.1 ıj | 4.9 s-u |
| Çağlı | 3036.3 r | 1913.1 st | 933.4 mn | 125.0 kl | 64.9 jk | 5.5 o-s |
| Doruk | 3902.4 k | 3066.7 j | 733.3 t | 72.6 rs | 29.8 r | 5.9 l-q |
| Innovator | 2954.2 s | 1398.8 y | 1325.0 fg | 155.4 hı | 75.0 gh | 9.5 cd |
| Jelly | 4922.6 e | 4092.9 d | 740.5 t | 46.4 t | 42.9 o | 7.1 g-ı |

Table 8 (continued)
Means of 2019 year total tuber yield ha$^{-1}$ (kg), large tuber yield ha$^{-1}$ (kg), medium tuber yield ha$^{-1}$ (kg), small tuber yield ha$^{-1}$ (kg), discarded tuber yield ha$^{-1}$ (kg), average number of buds tuber$^{-1}$ of 38 potato genotypes evaluated under Konya location.

| | | | | | | |
|---|---|---|---|---|---|---|
| Kutup | 3973.8 j | 3078.6 j | 785.7 rs | 90.5 o-q | 19.0 s | 6.0 k-p |
| L.O. | 3603.55 n | 2197.6 q | 1156.0 j | 165.5 gh | 84.5 e | 4.5 t-v |
| Leventbey | 3143.45 q | 2460.7 o | 560.7 x | 88.1 pq | 33.9 qr | 5.3 p-t |
| Madeleine | 4678.6 g | 3915.5 e | 684.5 u | 61.9 s | 16.7 s | 5.6 n-s |
| Marabel | 5538.7 c | 4782.8 b | 636.9 vw | 82.1 qr | 36.9 pq | 5.7 m-s |
| Melody | 4969.7 de | 3323.2 h | 1310.7 gh | 244.1 b | 91.7 cd | 4.1 uv |
| Muratbey | 2872.6 t | 2056.0 r | 676.2 u | 103.6 m-o | 36.9 pq | 7.5 gh |
| R.B. | 3466.7 o | 2288.1 p | 1061.9 k | 97.6 n-p | 19.0 s | 11.6 a |
| Vr808 | 4122.6 ı | 3139.3 l | 876.2 pq | 66.7 s | 40.5 op | 6.6 ı-l |
| Zirve | 5514.3 c | 3810.7 f | 1528.6 b | 125.0 kl | 50.0 n | 6.3 ı-o |
| AFAG12 | 3027.4 r | 1928.6 s | 943.5 m | 112.5 lm | 42.9 o | 10.5 b |
| AFAG-C | 4736.9 f | 3728.6 g | 806.5 r | 149.4 ı | 52.4 n | 7.8 fg |
| AFBR4 | 3366.7 p | 2986.9 k | 297.6 y | 65.5 s | 16.7 s | 5.0 r-t |
| AFHER 11 | 2414.9 x | 1267.9 y | 846.4 q | 217.3 de | 83.4 ef | 4.0 v |
| AFK3 | 3406.0 p | 1738.1 u | 1276.2 ı | 288.1 a | 103.6 b | 6.2 j-o |
| AFLA20 | 2627.3 v | 1615.5 w | 733.9 t | 206.4 ef | 71.4 hı | 6.8 h-k |
| AFLA9 | 3106.6 q | 1541.1 x | 1282.7 hı | 197.0 f | 85.7 e | 6.5 ı-m |
| ELAF10 | 5817.3 b | 4237.5 c | 1353.6 ef | 167.9 gh | 58.3 lm | 5.2 p-t |
| ELAF11 | 6029.8 a | 4946.4 a | 907.2 n-p | 122.6 kl | 53.6 mn | 6.3 l-o |
| GAF4 | 4158.9 ı | 2907.2 l | 979.2 l | 176.2 g | 96.4 c | 5.8 l-r |
| HEAF5 | 3693.5 m | 1872.1 t | 1494.1 c | 242.9 b | 84.5 e | 8.8 de |
| MK2 | 2001.2 z | 1129.2 z | 628.0 w | 166.7 gh | 77.4 g | 6.4 l-n |
| PAG5 | 3992.9 j | 2444.1 o | 1308.9 gh | 147.1 ıj | 92.9 c | 4.5 t-v |
| PAG9 | 2963.7 s | 1309.5 y | 1358.3 e | 217.9 de | 78.0 fg | 8.4 ef |
| T1AG14 | 2710.1 u | 1679.8 v | 688.1 u | 234.5 bc | 107.8 b | 9.9 bc |
| T2AG13 | 2226.2 y | 1611.3 w | 238.7 z | 222.0 cd | 154.2 a | 5.2 p-t |
| T3AG14 | 2535.1 w | 1660.7 v | 663.7 uv | 150.6 ı | 60.1 kl | 10.1 bc |
| T3LA8 | 2713.7 u | 1544.1 x | 914.3 m-o | 168.5 gh | 86.9 de | 3.9 v |
| T3PO13 | 2272.6 y | 1558.9 x | 557.1 x | 106.5 mn | 50.0 n | 5.1 q-t |
| T7LA8 | 4109.0 ı | 2756.6 m | 1002.4 l | 247.6 b | 102.4 b | 5.7 m-s |
| Mean | 3733.3 | 2563.2 | 949.0 | 157.7 | 63.5 | 6.5 |
| Lsd $_{\text{genotype (0.01)}}$ | 56.24 | 43.90 | 31.96 | 14.88 | 5.46 | 0.83 |

When the total tuber yield values for the first year of the experiment were examined; the trial average was calculated as 3733.3 kg da$^{-1}$. The highest tuber yield was obtained from the ELAF11 line with 6029.8 kg da-$^{1}$, and the lowest tuber yield was found in the MK2 line with 2001.2 kg da$^{-1}$ (Table 8). It is known that yield values are closely related to tuber numbers per hill, tuber yield per hill and number of main stems. All of these parameters were determined at lower value in the field season of 2019 compared to the values of 2020. When the total tuber yield values are evaluated in terms of locations, Konya location is ahead of Karaman location (4000.5 kg da$^{-1}$) with 4416.7 kg da$^{-1}$. As genotype averages; while the highest yield (5248.5 kg da$^{-1}$) was obtained from Zirve variety, the lowest yield was determined from Russet Burbank variety with 3165.3 kg da$^{-1}$ and PAG5 lines with 3226.2 kg da$^{-1}$.When the location x genotype interaction values are examined; the highest yield was obtained from the Zirve variety in Konya location with 5598.2 kg da$^{-1}$, and the lowest yield was obtained from the AFAG-C line in Karaman location with 2766.4 kg da$^{-1}$ (Table 9).

Table 9
Means of two locations for total tuber yield da$^{-1}$ (kg), large tuber yield da$^{-1}$ (kg), medium tuber yield ha$^{-1}$ (kg), small tuber yield ha$^{-1}$ (kg), discarded tuber yield ha$^{-1}$ (kg), average number of buds tuber$^{-1}$ of 15 potato genotypes evaluated in 2020 year.

| Genotypes | Total tuber yield ha$^{-1}$ | | | Large tuber yield | | | Medium tuber yield ha$^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Konya | Karaman | Mean | Konya | Karaman | Mean | Konya | Karaman | Mean |
| Agria | 3562.9 k-m | 4119.1 gh | 3841.0 h | 1865.2 e-g | 741.1 r | 1303.1 h | 1019.3 m-o | 1006.0 m-o | 1012.6 ıj |
| Brooke | 5258.2 b | 3739.6 jk | 4498.9 de | 2168.9 cd | 1571.4 ı-k | 1870.2 c | 2038.7 b | 1517.9 e-g | 1778.3 b |
| Doruk | 5271.8 b | 4811.0 cd | 5041.4 b | 1765.0 gh | 3142.9 a | 2454.0 a | 1853.1 c | 1034.2 m-o | 1443.6 e |
| Kutup | 4534.7 ef | 4864.6 cd | 4699.6 c | 1234.3 m-o | 3080.4 a | 2157.3 b | 1610.6 d-f | 1256.0 ıj | 1433.3 ef |
| L.O. | 3677.4 kl | 4020.8 hı | 3849.1 h | 1746.4 gh | 1065.5 op | 1405.9 f-h | 1139.3 j-m | 1369.1 hı | 1254.2 gh |
| Melody | 4344.8 fg | 4710.7 de | 4527.8 d | 1035.7 pq | 2407.2 b | 1721.4 d | 1645.1 de | 1442.9 gh | 1544.0 d |
| R.B. | 3086.5 op | 3244.1 no | 3165.3 j | 1291.2 l-n | 1699.4 g-ı | 1495.3 ef | 1192.8 j-l | 913.7 o | 1053.3 ı |
| Zirve | 5598.2 a | 4898.8 cd | 5248.5 a | 2339.3 bc | 2511.9 b | 2425.6 a | 2374.3 a | 1675.6 d | 2024.9 a |
| AFAG-C | 4344.5 fg | 2766.4 q | 3555.5 ı | 2220.5 c | 1440.5 kl | 1830.5 cd | 1225.7 jk | 608.6 p | 917.2 j |
| AFBR4 | 4319.8 fg | 3571.4 k-m | 3945.6 gh | 1154.8 n-p | 1523.8 jk | 1339.3 gh | 1729.5 cd | 949.4 no | 1339.5 fg |
| ELAF10 | 5362.4 b | 3356.6 mn | 4359.5 e | 2038.7 de | 1066.8 op | 1552.8 e | 2404.8 a | 921.8 o | 1663.3 c |

Table 9 (continued)
Means of two locations for total tuber yield da$^{-1}$ (kg), large tuber yield da$^{-1}$ (kg), medium tuber yield ha$^{-1}$ (kg), small tuber yield ha$^{-1}$ (kg), discarded tuber yield ha$^{-1}$ (kg), average number of buds tuber$^{-1}$ of 15 potato genotypes evaluated in 2020 year.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ELAF11 | 5025.8 c | 4854.1 cd | 4939.9 b | 2192.3 cd | 1978.2 ef | 2085.2 b | 1096.1 k-m | 1486.3f-hj | 1291.2 g |
| GAF 4 | 4377.6 f | 3792.5 ı-k | 4085.1 fg | 2232.0 c | 1402.6 k-m | 1817.3 cd | 1267.0 ıj | 1431.0 gh | 1349.0 e-g |
| PAG 5 | 3505.9 lm | 2946.4 pq | 3226.2 j | 1804.8 f-h | 867.9 qr | 1336.3 h | 1022.6 m-o | 933.3 no | 978.0 ıj |
| T7LA8 | 3964.3 h-j | 4311.0 fg | 4137.7 f | 1656.0 h-j | 1264.9 mn | 1460.4 e-g | 1273.8 ıj | 1071.5 l-n | 1172.6 h |
| Mean | 4416.7 a | 4000.5 b | 4208.1 | 1783.0 a | 1717.6 b | 1750.3 | 1526.2 a | 1174.5 b | 1350.3 |
| Lsd $_{genotype\ (0.01)}$= 163.7 | | | | Lsd $_{genotype\ (0.01)}$ = 123.2 | | | Lsd $_{genotype\ (0.01)}$ =99.09 | | |
| Lsd $_{locationx\ genotype\ (0.01)}$ = 231.6 | | | | Lsd $_{locationx\ genotype\ (0.01)}$ = 174.2 | | | Lsd $_{locationx\ genotype\ (0.01)}$ = 140.1 | | |
| Genotypes | Small tuber yield | | | Discarded tuber yield | | | Average number | | |
| | Konya | Karaman | Mean | Konya | Karaman | Mean | Konya | Karaman | Mean |
| Agria | 466.1 n-p | 1863.1 a | 1164.6 a | 212.3 hı | 508.9 b | 360.6 c | 13.0 d | 10.1 h-j | 11.6 c |
| Brooke | 647.3 jk | 583.3 k-m | 615.3 h | 403.3 c | 67.0 l | 235.1 de | 11.4 fg | 9.9 ıj | 10.6 d |
| Doruk | 1465.6 d | 445.0 op | 955.3 de | 188.1 hı | 189.0 hı | 188.6 f-h | 8.9 kl | 8.3 lm | 8.6 f |
| Kutup | 1572.6 c | 312.5 q | 942.5 e | 117.4 j-l | 215.8 g-ı | 166.6 g-ı | 14.8 c | 8.3 lm | 11.5 c |
| L.O. | 629.8 j-l | 1410.7 d | 1020.2 c | 161.9 ı-k | 175.6 hı | 168.8 g-ı | 12.1 d-f | 10.8 g-ı | 11.4 c |
| Melody | 1484.5 d | 767.9 hı | 1126.2 ab | 179.5 hı | 92.8 l | 136.2 ı | 8.3 lm | 5.5 qr | 6.9 h |
| R.B. | 500.6 m-p | 431.6 p | 466.1 ı | 101.9 l | 199.4 hı | 150.6 hı | 19.9 a | 17.5 b | 18.7 a |
| Zirve | 704.6 ıj | 479.2 n-p | 591.9 h | 180.1 hı | 232.2 f-h | 206.1 e-g | 10.9 gh | 12.4 de | 11.6 c |
| AFAG-C | 286.9 q | 546.1 l-n | 416.5 ı | 610.9 a | 171.2 ıj | 391.0 bc | 11.6 e-g | 12.1 d-f | 11.9 c |
| AFBR4 | 1117.9 ef | 904.8 g | 1011.4 cd | 317.6 de | 193.5 hı | 255.5 d | 9.3 jk | 5.0 r | 7.1 gh |
| ELAF10 | 770.1 hı | 1173.0 e | 971.5 c-e | 178.6 hı | 195.1 hı | 186.8 f-h | 9.4 jk | 6.0 pq | 7.7 g |
| ELAF11 | 1129.0 ef | 1059.9 f | 1094.4 b | 608.5 a | 329.7 d | 469.1 a | 14.4 c | 12.1 d-f | 13.3 b |
| GAF 4 | 699.1 ıj | 851.0 gh | 775.1 f | 179.5 hı | 107.9 kl | 143.7 b | 7.0 no | 6.8 op | 6.9 h |
| PAG 5 | 516.7 m-o | 875.0 g | 695.8 g | 161.9 ı-k | 270.3 e-g | 216.1 d-f | 11.0 gh | 7.9 mn | 9.4 e |
| T7LA8 | 466.7 n-p | 1699.4 b | 1083.1 b | 567.9 a | 275.3 d-f | 421.6 b | 11.1 g | 6.1 o-q | 8.6 f |
| Mean | 830.5 b | 893.5 a | 862.0 | 278.0 a | 214.9 b | 246.4 | 11.5 a | 9.2 b | 10.4 |
| Lsd $_{genotype\ (0.01)}$ = 59.61 | | | | Lsd $_{genotype\ (0.01)}$ =40.41 | | | Lsd $_{genotype\ (0.01)}$ =0.66 | | |
| Lsd $_{locationx\ genotype\ (0.01)}$= 84.30 | | | | Lsd $_{locationx\ genotype\ (0.01)}$ = 57.15 | | | Lsd $_{locationx\ genotype\ (0.01)}$ = 0.93 | | |

In potatoes; yield, number of tuber, tuber size, specific gravity and some quality parameters vary greatly according to environmental conditions (Jansky, 2009). The variety candidate must be tested in various locations before acquiring cultivar features. Different locations require standardization of a set of characters affected by environmental conditions and allow to determine the adaptation (Maharijaya et al., 2021). However, it should be taken into account that yield and quality losses pose a potential risk, as new cultivar candidates create phenotypical variations according to environmental conditions (Gold et al., 2020). Total tuber yield values per decare; variation according to genotypes used, location and years were shown. Although the yield values obtained from the Konya location for 2020 were higher than the Karaman values (Table 9); number of tuber per hill and tuber yield values per hill (Table 7) were recorded higher in parallel with this.

As the seed tuber size decreases, tuber yield also decreases. The increase in seed tuber size increases both the number of main stems and the rate of marketable tuber (Yilmaz, 1995). The variation in total tuber yields per decare on the based on locations, years and genotypes has also caused large tuber yields per decare to differ. At the same time, the change in tuber size is an expected result. In this study, large tuber yield values per decare were recorded from Konya location compared to Karaman. Genotypes have had different responses to different environments. This situation was also noted in the results of some researchers on the subject (Yilmaz, 1995; Kara, 2002; Sari et al., 2017; Sanli et al., 2020).

Many factors can be related to the size of the tuber. For example, with delayed harvest, total number of tuber, percentage of large and medium tubers, total tuber yield and plant dry biomass increase (Khan et al., 2011). In a study in which a significant and negative correlation was found between total tuber yield and medium tuber ratio, it was determined that the two main contributors to total tuber yield were average tuber weight and tuber weight per plant (Arslan, 2007). There were obvious differences between locations in the medium tuber yields of this study. This situation was also reflected in the location x genotype interactions. When the average tuber yield per decare was examined, values for the 2020 year were higher than that of 2019. In addition, medium tuber yields in tuber distributions were higher in Konya location (Table 9). The values obtained in terms of medium tuber yields, were found Kara et al. (2002)'s findings closer to the upper limit, Ozturk et al. (2007) 's findings quite higher than the limits.

Considering the trial averages of small tuber yield per decare, 2020 was found to be higher. In addition, based on location in tuber distribution, small tuber yields were higher in Karaman location. Many researchers found small tuber yields per decare in different ranges. These values were; according to 2019 data, it was close to the lower limit of Kara (2002) (136.4-376.7 kg/da), Ozturk et al. (2007) (119.5 kg/da-289.5 kg/da). Yield

values for 2020; remained at high values like other large and medium tuber yield parameters. The increase in total yield can be explained by the change in tuber distribution and the increase in values.

Considering the trial averages of discarded tuber yield per decare, it was found that higher values were found in 2020 compared to 2019 (278.0 kg/da) (Table 9). In addition, discarded tuber yields based on location in tuber distributions were higher in Konya. Caliskan (2001) and Sanli and Karadogan (2012) reported that the lower tuber size in cultivars with a high number of tuber per hill and low tuber yield per hill caused an increase in discarded tuber yield. Although this is also valid for the discarded tuber yields of this study; it may also be a result related to environmental conditions and the development status of plants.

The number of eyes in the tuber in both years of the trial; according to the genotype used, location and years varied. The trial average of the average number of eyes in tuber in 2019 was 6.5 pieces (Table 9). According to the data of 2020; when the number of eyes in the tuber were compared in terms of location, Konya location surpassed Karaman location (9.2 pieces) with 11.5 pieces. According to the genotype averages; Russet Burbank with the highest value 18.7 pieces/tuber. While it represented group (a), the lowest value was detected in GAF4 line and Melody variety with 6.9 pieces and took place in the same group (g). The location x genotype interactions; Konya x Russet Burbank with 19.9 pieces/tuber. The trial average was calculated as 10.4 pieces/tuber (Table 9). The number of eyes per tuber increases with tuber size. At the same time, it is known that the eyes of tubers with large seeds are larger than the eyes of tubers with small seeds, and the differences are due to the variety (Allen, 1978). Many researchers have reported that increasing the number of eyes also increases the tuber yield, on the contrary, the average tuber yield decreases (Mahmud et al. 2010; Sanli et al., 2015). According to the number of eyes in the tuber of this research; Although the number of eyes per tuber was higher in Konya location (Table 8 and Table 9), the number of tubers per hill (Table 6 and Table 7) and the total tuber yield per decare (Table 8 and Table 9) were also higher in the same location. This result confirms the opinion of the researchers mentioned above.

Maturation time was classified according to the drying periods of the upper part of the plant. There is a significant relationship between tuber maturation time, tuber yield and starch content. Late maturing varieties tend to produce higher tuber and starch yields (van Eck, 2007; Camire et al., 2009). Also, late maturing cultivars have higher yield potential than early maturing cultivars. Among the reasons potato varieties and lines mature at different times in terms of year and location; environmental conditions, temperature, day length and characteristic features of the variety can be counted. In terms of environmental conditions, the fact that the vegetative part of the plant stays alive longer in years or locations where precipitation or irrigation is good causes the maturation period to prolong. In addition, the ripening period is prolonged in high and cool areas (Yilmaz and Tugay, 1999). The two most important factors affecting the storage quality of potatoes are dormancy periods and maturation characteristics. it is imperative to adjust the storage time and temperature by paying attention to the variety characteristics (Ozcan et al., 2019). For this reason, the maturation time parameters must be taken for their storage resistance. In general, when the studies with standard varieties were examined; In terms of maturation times, many researchers were recorded values similar to the scale values determined in this study (Şanlı and Karadoğan, 2012; Karan, 2013; Bülbül, 2018).

Table 10
Maturation time[A], plant growth type[B], tuber shape[C] scale values of the trial conducted in Konya location in 2019*

| Varieties | A | B | C | Lines | A | B | C |
|---|---|---|---|---|---|---|---|
| Agata | 1 | 5 | 7 | AFAG12 | 5 | 5 | 7 |
| Agria | 5 | 3 | 7 | AFAG-C | 5 | 3 | 3 |
| Brooke | 5 | 7 | 5 | AFBR4 | 7 | 5 | 7 |
| Challenger | 5 | 5 | 7 | AFHER 11 | 5 | 7 | 8 |
| Çağlı | 3 | 5 | 7 | AFK3 | 5 | 7 | 5 |
| Doruk | 7 | 3 | 3 | AFLA20 | 5 | 3 | 3 |
| Innovator | 5 | 3 | 8 | AFLA9 | 7 | 5 | 8 |
| Jelly | 7 | 3 | 7 | ELAF10 | 5 | 5 | 3 |
| Kutup | 5 | 5 | 7 | ELAF11 | 5 | 5 | 5 |
| L.O. | 5 | 5 | 7 | GAF4 | 7 | 3 | 5 |
| Leventbey | 5 | 5 | 5 | HEAF5 | 3 | 5 | 3 |
| Madeleine | 7 | 3 | 7 | MK2 | 3 | 3 | 7 |
| Marabel | 5 | 5 | 7 | PAG5 | 5 | 3 | 7 |
| Melody | 7 | 5 | 5 | PAG9 | 3 | 3 | 7 |
| Muratbey | 5 | 3 | 7 | T1AG14 | 5 | 5 | 8 |
| R.B. | 5 | 5 | 8 | T2AG13 | 9 | 5 | 7 |
| Vr808 | 5 | 7 | 3 | T3AG14 | 5 | 5 | 7 |
| Zirve | 5 | 5 | 5 | T3LA8 | 7 | 5 | 8 |
| | | | | T3PO13 | 3 | 3 | 3 |
| | | | | T7LA8 | 7 | 5 | 8 |

*A: 1 = very early, 3 = early, 5 = medium early, 7 = late, 9 = very late; B: 3= upright, 5= semi-upright, 7=tilt; C: 1=(<98mm) inverted oval, 2=(98mm-104mm) round, 3=(104mm-110mm) round-oval, 4= (110mm-120mm) oval round, 5= (120mm-130mm) oval, 6=(130mm-145mm) oval long, 7= (145mm-160mm) long oval, 8= (160mm-200mm) long, 9=(>200mm) very long

Table 11
Maturation time[A], plant growth type[B], tuber shape[C] scale values of the trials conducted in Konya[1] and Karaman-Akcasehir[2] locations in 2020*

| Genotypes | A1 | A2 | B1 | B2 | C1 | C2 |
|---|---|---|---|---|---|---|
| Agria | 5 | 7 | 3 | 3 | 7 | 3 |
| Brooke | 5 | 5 | 7 | 7 | 3 | 5 |
| Doruk | 7 | 7 | 3 | 3 | 3 | 3 |
| Kutup | 5 | 5 | 5 | 5 | 7 | 3 |
| L.O. | 5 | 5 | 5 | 5 | 8 | 7 |
| Melody | 7 | 7 | 5 | 5 | 3 | 3 |
| R.B. | 5 | 5 | 5 | 5 | 9 | 8 |
| Zirve | 5 | 5 | 5 | 5 | 1 | 7 |
| AFAG-C | 5 | 5 | 3 | 3 | 7 | 8 |
| AFBR4 | 7 | 7 | 5 | 5 | 7 | 7 |
| ELAF10 | 5 | 7 | 5 | 3 | 3 | 5 |
| ELAF11 | 5 | 5 | 5 | 3 | 3 | 3 |
| GAF4 | 7 | 7 | 3 | 3 | 5 | 5 |
| PAG5 | 7 | 5 | 3 | 3 | 8 | 7 |
| T7LA8 | 5 | 7 | 5 | 7 | 8 | 5 |

*A: 1 = very early, 3 = early, 5 = medium early, 7 = late, 9 = very late; B: 3= upright, 5= semi-upright, 7=tilt; C: 1=(<98mm) inverted oval, 2=(98mm-104mm) round, 3=(104mm-110mm) round-oval, 4= (110mm-120mm) oval round, 5= (120mm-130mm) oval, 6=(130mm-145mm) oval long, 7= (145mm-160mm) long oval, 8= (160mm-200mm) long, 9=(>200mm) very long

The plant growth type was recorded by observation when the plants started to cover the soil. Selection criteria based on phenotypes, such as plant growth type, flower and leaf colors, are grouped according to certain scales with the eye of the breeder. In this way, the breeder obtains information about the plant and selects it in terms of plant growth. As a plant type, upright growing plants have a higher leaf area index and benefit more from light (Beukema and van der Zaag, 1990).

When both years are compared in tuber shape scale values, Brooke, ELAF11, Melody, PAG5, Russet Burbank, Lady Olympia, AFAG-C and Zirve genotypes are among the genotypes that differ in tuber shape. Consumer market share is directly related to the size of potato tubers. Producers aim to implement the breeding program in such a way as to get the best yield in field production in order to maximize tuber size. Tuber size varies with many different growing packages and applications in the field. For example; Inter-row and above-row applications, late sowing, early harvest, amount of fertilizer and water inputs, different growth regulators, and changing the physiological age of seed tuber can be counted (Pavek, 2014). The length/width ratio of the potato tuber is an indicator of the phenotype shape of the tuber used in potato breeding (Si et al., 2018). In this study, most of the lines in the 2019 season were eliminated due to the tuber type in amorphous structure. When evaluated in general; Although tuber size scales of cultivars are cultivar characteristics, there was an increase and decrease in tuber size in some genotypes related to yield and yield components.

## 4. Coclusion

Tuber yield is accepted as the main criterion in potato breeding. According to the 2019 growing season; when the lines were evaluated, the highest tuber yields per decare were obtained in the ELAF11 (6029.8 kg da$^{-1}$) line. However, yield values differ in year and location; It was determined as 5362.4 kg da$^{-1}$ in the ELAF10 line for 2020 and was determined below the 2019 trial average. The distribution of large and medium tubers per decare is as important as the total tuber yield per decare. Marketable tuber yield is preferred because it is the size demanded by the consumer. In addition, there are certain size standards for chips and French-fries. On the other hand, tuber shape is the breeding criterion sought to minimize shell loss. The presence of amorphous tubers negatively affects the peeling efficiency and is one of the most important consumer preference criteria. Accordingly, although it varies according to the growing regions and years, the lines are generally recorded as round oval, oval shape. In addition, the tuber shape of the GAF4 and PAG5 lines was one of the most striking lines. As a result of the field studies, ELAF11 and ELAF10 lines were determined as potato breeding lines with high tuber yields.

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**Research Article**

# Evaluation of Physical and Quality Traits of Local Potato Breeding Lines During Long Term Storage

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**ABSTRACT**

This study aimed to determine the potato breeding lines that show superior storage traits and can be candidate variety by selection. The storage study was carried out in the first year according to The Randomized Plots Trial Design and the second year according to The Randomized Plots in Factorial Trial Design with four replications. In the study, 20 potato breeding lines developed by Selcuk University, Faculty of Agriculture, Department of Field Crops and 18 registered varieties as plant material were used in the first year. In the second year, the study continued with 7 breeding lines and 8 registered varieties that selected in the first year. The varieties and lines were done harvest in the fields and then the genotypes were evaluated according to physical and quality traits with storage trials (+ 4 °C, 6 months). In the study; ratio of dry matter (%), yield of leaf chips (%), yield of French fries (%), quality of leaf chips (1-5 scale), quality of French fries (0-4 scale), blackening (1-5 scale), storage weight loss (%), the first shoot formation time (day) parameters were examined. The ratio of dry matter, yield of leaf chips, and French fries values increased compared to the pre-storage period. Among the promising lines in terms of dry matter ratio changes; T7LA8 (20.9 %-24.8 % in 2019,19.0 %-21.1 % in 2020 according to the genotype average values), PAG5 (22.6 %-20.5 % in 2019, 20.0 %-19.0 % in 2020 according to the genotype average values), GAF4 (18.7 %-21.6 % in 2019, 18.4 %-20.7 % in 2020 according to the genotype average values) can be counted. As a result of the study, T7LA8, PAG5 and GAF4 lines with high ratio of dry matter, yields of chips and French fries were determined as promising lines.

## 1. Introduction

The potato consumption market is divided into seven main groups. These are fresh consumption, frozen potato products, potatoes for chips and French fries, dried potatoes, starch, seeds and other industrial groups. Since it is so essential in human nutrition, the development of potato varieties with high field performance, resistance to disease, pests and storage is gradually increasing (Bond, 2014).

Potato breeding objectives can be summarized as yield, tuber quality, resistance to biotic and abiotic environmental restrictions. As for the quality parameters, they can be restricted into two categories. The first is the visible features of the tuber (size, shell color, tuber length, shape and depth of the eye). This group targets consumer desires, in other words, fresh consumption. The second category is the internal properties of the tuber (nutritional content, cooking, processing properties). They are closely related to the content of dry matter, taste, sugar, protein content, starch quality and the amount of glycoalcoholoids (Carputo and Frusciante, 2011).

The selection criteria continue after the field in potato breeding. Because potato tubers contain a high percentage of water, they should be stored in healthy storage conditions. The main factor restricting the processing capacities of potato tubers is the rate of sugar accumulation, which decreases during storage. The durability of storage is one of the most critical breeding objectives for the healthy continuation of the breeding program (Hoopes and Plaisted, 1987; Richardson et al, 1990).

The quality and storage time of potatoes are reduced by moisture loss, decay and physiological deterioration of the tuber. These losses are related to the storage temperature, relative humidity, ventilation and gas compo-

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sition. Since potatoes are living organism, it needs an effective storage system. Potatoes are stored in modern storage structures, cellars, storerooms, earthen silos, and storages made of volcanic rocks (Ozturk, 2010; Sanli, 2012).

After harvesting, the tubers remain in their dormant natural state for 1-15 weeks (Wiltshire and Cobb, 1996). Potato tubers should be placed in storage with an equal distribution of piles after harvesting with the conditions of air circulation is provided, the temperature is maintained at a 15 ° C and relative humidity is between 90-95 % provided. Then, the storage temperature should be kept at 10-12 °C for two weeks to ensure the healing and hardening of the tuber shells (curing period). After this period, the storage temperature should be determined according to the intended use of the tubers (Shetty, 2010).

One month after harvesting, the increased elevated storage temperatures should be reduced to a minimum of 5-6 ° C. Lowering it to temperatures below this temperature increases the respiratory rate of tubers. The high increase in respiratory rate is due to the breaking of dormancy and the extension of exiles. While the formed exiles give off heat to the outside, the sproutings are increasing. As a result, the storage system is negatively affected and this situation sets the stage for product losses (Pringle et al., 2009). Storage weight losses amount to about 10% of the total weight loss over a storage period of 6-8 months (Wustman and Struik, 2007).

Storage requirements vary depending on the purpose of consumption of tubers. Tubers to be used for seed purposes should be stored in storage to give exiles sufficient give exiles with sufficient height and characteristics without losing their exile capabilities in the time until the next planting season. Potatoes that will be consumed as food in the coming times should also be stored in storages that will prevent the development of exiles from preventing spoilage, softening, and some other undesirable conditions. Moreover, the tubers in the industry should be stored in storage that will ensure the preservation of the starch-sugar ratio associated with technological quality (Sanli, 2012).

This study aimed to evaluate the storage performance of some trade registered potato varieties and promising variety lines selected as 5th field generation in the breeding program by Associate Professor Rahim Ada and determine the lines that can be variety candidates by making an intended selection.

## 2. Materials and Methods

In the first year of study, 20 promising potato lines developed by Associate Professor Rahim ADA and 18 standard potato varieties were used. In the second year, the performances of 7 promising potato lines and 8 standard potato varieties that were selected from the first year were evaluated in storage parameters. The breeding lines were selected as crossbreed seeds that were developed to 5th field generation by selection. The information about these lines and varieties were shown in the Table 1.

In the storage procedure, all genotypes produced and harvested in Konya for the first year and both in Konya and Karaman-Akçaşehir locations for the second year at 2019-2020 vegetation periods. Field studies were conducted at Selcuk University Faculty of Agriculture Abdulkadir Akcin Trial Field in Konya, and Karaman-Akcasehir farmer field. Exactly 5 kg per each was taken from the potato tubers harvested as starting material and they were put into a store at which temperature + 4 °C and store humidity at 90-98 %. Total storage period was 6 months. At the end of the storage periods, 30 tubers were randomly selected from all genotypes and the physical and chemical properties of tubers were determined.

The storage study was carried out in the first year according to the 'The Randomized Plots Trial Design' and the second year according to 'The Randomized Plots in Factorial Trial Design' with four replications. In the study; ratio of dry matter (%), yield of leaf chips (%), yield of French fries (%), quality of leaf chips (1-5 scale), quality of french fries (0-4 scale), blackening (1-5 scale), storage weight loss (%), the first shoot formation time (day) parameters were examined. The parameters of the varieties and lines examined in the storage conditions were determined before and after the storage.

The data were analyzed using technique of analysis of variance (JUMP) and treatment means were separated by Least Significant Differences (LSD) at 1 % probability level by using MSTAT-C as described by Nissen (1989).

Below methods were used for analyses of tuber samples taken from potato genotypes.

-Ratio of dry matter (%): The tuber samples belonging to the genotypes were first washed before and after storage, then dried and sliced. 100 g sample was taken from each and dried under the laboratory conditions. Then 24 hours in the drying chamber set up to 105 °C, reweighted and dry matter ratios were calculated by proportioning their fresh weights (Kacar, 1972). The data obtained were recorded as pre-storage and post-storage separately.

-Yield of leaf chips (%): After the potato tubers were washed and sliced with chips slicer (at the thickness of 1.0-1.5 mm), 100 g per each was weighted, washed in cold water and dewatered between two towels. Then the slices at the weight of 100 g were fried at 190 °C for 2 minutes and after cooling, all the samples were weighted and their values were calculated before and after storage as percentage of fresh weight (Senol, 1973). Obtained values were recorded as pre-storage and post-storage separately.

-Yield of French fries (%): After the potato tubers were washed and sliced with chips slicer (at the thickness of 1.0 cm), 100 g per each was weighted, washed in cold water and dewatered between two towels. Then the slices at the weight of 100 g were fried at 190 °C for

3 minutes and after cooling, the all samples were weighted and their values were calculated before and after storage as a percentage of fresh weight (Ross ve Porter, 1969). Obtained values were recorded as pre-storage and post-storage separately.

- Quality of leaf chips (1-5 scale): The samples used for chips yield were recorded according to grouping as pre-storage and post-storage separately (1 = No chips, 2 = Risky, 3 = Medium, 4 = Good, 5 = Very good) (Anonymous, 2001).

-Quality of french fries (0-4 scale): The samples used for French-fries yield were recorded according to grouping as pre-storage and post-storage seperately (0 = Very good, 1 = Good, 2 = Fair – good, 3 = Medium (max 30%), 4 = Low (max 10%)) (Anonymous, 2001).

-Blackening (1-5 scale): 5 tubers taken randomly from each plot were washed, divided into 3 lengthwise and after waiting for 30 minutes, evaluation was made according to the grouping as pre-storage and post-storage seperately (1 = V-shaped darkening, 2 = Significant darkening, 3 = Slight darkening, 4 = Local darkening, 5 = No darkening) (Anonymous, 2001).

-Storage weight loss (%): 5 kg of available tubers of all varieties and breeding lines were weighed and stored. These stored tubers were weighed again at the beginning and after the storage (6 months), and the difference was expressed as weight loss in % by proportioning to the first weighing (Ozturk et al., 2016).

-The first shoot formation time (day): The first shoot formation time of 5 kg tubers of each variety and breeding line used to determine storage weight change was checked at 15-day intervals and recorded per day.

Table 1
Information on potato varieties and breeding lines used in the study

| Varieties | Usage | Varieties | Usage | Lines | Usage | Lines | Usage |
|---|---|---|---|---|---|---|---|
| VR 808 | Chips | Marabel | Cooking | AFAG-C | Chips | ELAF-10 | Cooking |
| Brooke | Chips | Agata | Cooking | HEAF-5 | Chips | ELAF-11 | Cooking |
| Doruk | Chips | Madeleine | Cooking | T7LA-8 | French fry | T3AG-14 | Cooking |
| Russet Burbank (R.B.) | French fry | Melody | Cooking | PA-9 | French fry | T1AG-14 | Cooking |
| Lady Olimpia (L.O.) | French fry | Zirve | Cooking | AFLA-9 | French fry | T2AG-13 | Cooking |
| Innovator | French fry | Çağlı | Cooking | AFLA-20 | French fry | T3PO-13 | Cooking |
| Kutup | French fry | Leventbey | Cooking | AFHE-11 | French fry | T3LA-8 | Cooking |
| Agria | Cooking-Chips | Muratbey | Cooking | MK-2 | Cooking | PAG-5 | Cooking |
| Jelly | Cooking-Chips | | | AFK-3 | Cooking | AFBR-4 | Cooking |
| Challenger | Cooking-Chips | | | GAF-4 | Cooking | AFAG-12 | Cooking |

## 3. Results and Discussion

The variance sources and their statistical significance are shown in Table 2 and 3 for the physical and quality traits. Data of variance analysis in Table 2 showed that the effect of the genotypes on all parameters, both pre-storage and post-storage were statistically significant at 1 % probability level. Data of variance analysis in Table 3 showed that locations, genotypes, and location x genotype interactions on all both pre-storage and post-storage parameters were statistically significant at 1 % probability level.

According to ratio of dry matter from storage tubers in the first year, while average pre-storage ratio of dry matter was 18.8 %, this rate was recorded as 19.5 % after storage and increased. When ratios of dry matter before storage were examined; T3PO13 with 22.8 %, PAG5 with 22.6 % and VR808 with 22.5 % were recorded as the highest values and were in the group (a). The lowest ratio of dry matter of 13.9 % was determined in Agata variety and classified in (r) group. The highest ratio of dry matter after storage; It was determined in the T7LA8 line with 24.8 % and with this value it was included in group (a). The lowest ratio of dry matter was determined from the AFRR4 line with 16.1 % and formed the (u) group. Storage changes; Although there was a decrease in some varieties and lines, it was generally in the direction of increase (Table 4).

According to ratio of dry matter from storaged tubers in the second year; While the trial average before storage was 19.1 %, it was recorded as 19.5 % after storage. There was a relative increase. When the pre-storage data was examined, Konya location surpassed Karaman location (18.9 %) with 19.4 % in terms of location. According to the genotype averages; While Doruk variety with 22.9 % was in group (a), the lowest ratio of dry matter was determined in Melody variety with 14.3 % and was recorded in group (i). When the post-storage values were examined, a higher value was recorded in the Konya location with 20.1 % than in the Karaman location (18.9 %). According to the genotype averages; Brooke variety was found (a) group with 22.4 %, Melody variety was recorded (k) group with 15.8 %. Although there were fluctuations, the general trend was towards increasing the post-storage data (Table 5).

The starch content largely determines the ratio of dry matter in potato tubers. Starch content is significant for the processing industry and the fresh market as it affects the texture of the potato. The variation of dry matter ratio is closely related to the genetics of the variety, growing conditions, growing season, and storage temperature. A higher dry matter ratio was determined during the growing season in potato tubers grown in the spring. In addition, the ratio of dry matter differences between

varieties is closely related to the vegetation period. Early maturing potato varieties have less dry matter accumulation than late maturing ones (de Freitas et al., 2006; Jansky, 2009; Kawchuk et al., 2008). High dry matter ratio; It increases the yield of chips, provides a crispy consistency in the mouth and less oil extraction during frying (Pedreschi et al., 2005; Rommens et al., 2010).

In this study, according to both 2019 and 2020 data; There was a general increase in storage change. This increasing trend might be due to weight loss of tubers through respiration and transpiration. Because, as is known, tubers, which are alive right after harvest, lose weight by dehydration through respiration (Er and Uranbey, 1998; Ozturk and Polat, 2016). Similar to this result, it was reported in many studies that dry matter and dry matter constituents increased relatively in potato tubers during storage (Kara, 1996; Haase et al., 2007; Sanli, 2012; Broćić et al., 2016).

Table 2
Results of variance analysis of the physical and quality traits in the study conducted in 2019

| Source of Variation | | Means square | | | | | |
|---|---|---|---|---|---|---|---|
| | | Ratio of Dry Matter (%) | | Yield of leaf chips (%) | | Yield of French fries (%) | |
| | df | Pre-storage | Post-storage | Pre-storage | Post-storage | Pre-storage | Post-storage |
| Recurrence | 3 | 0.03 | 0.03 | 0.08 | 0.05 | 0.40 | 0.14 |
| Genotypes | 37 | 19.13** | 18.27** | 109.40** | 149.37** | 78.42** | 10.93** |
| Error | 111 | 0.03 | 0.03 | 0.04 | 0.38 | 0.69 | 0.09 |

| Source of Variation | df | Storage weight loss (%) | The first shoot formation time (day) |
|---|---|---|---|
| Recurrence | 3 | 0.03 | 0.36 |
| Genotypes | 37 | 27.75** | 854.59** |
| Error | 111 | 0.04 | 1.64 |

*P < 0.05, **P < 0.01

Table 3
Results of variance analysis of the physical and quality traits in the study conducted in 2020

| Source of Variation | | Means square | | | | | |
|---|---|---|---|---|---|---|---|
| | | Ratio of Dry Matter (%) | | Yield of leaf chips (%) | | Yield of French fries (%) | |
| | df | Pre-storage | Post-storage | Pre-storage | Post-storage | Pre-storage | Post-storage |
| Location | 1 | 6.63** | 47.38** | 84.84** | 139.96** | 74.89** | 27.08** |
| Recurrence [L] | 6 | 0.17 | 0.03 | 0.52 | 0.68 | 0.06 | 0.49 |
| Genotype | 14 | 37.78** | 30.12** | 183.60** | 362.90** | 222.40** | 332.00** |
| L x G | 14 | 8.08** | 4.41** | 83.37** | 59.57** | 29.29** | 50.96** |
| Error | 84 | 0.16 | 0.03 | 0.31 | 0.68 | 0.17 | 0.31 |

| Source of Variation | df | Storage weight loss (%) | The first shoot formation time (day) |
|---|---|---|---|
| Location | 1 | 518.34** | 6049.20** |
| Recurrence [L] | 6 | 0.01 | 9.58 |
| Genotype | 14 | 38.95** | 2034.95** |
| L x G | 14 | 29.59** | 1687.58** |
| Error | 84 | 0.03 | 9.12 |

*P < 0.05, **P < 0.01

Table 4
Means of physical and quality traits of 38 potato genotypes in storage conditions in 2019 year.

| Genotypes | Ratio of Dry Matter (%) | | Yield of leaf chips (%) | | Yield of French fries (%) | | Storage weight loss (%) | The first shoot formation time (day) |
|---|---|---|---|---|---|---|---|---|
| | Pre-storage | Post-storage | Pre-storage | Post-storage | Pre-storage | Post-storage | | |
| Agata | 13.9 r | 17.3 qr | 32.7 w | 50.8 m | 47.5 o-q | 52.9 v | 7.8 g | 37 q |
| Agria | 18.1 l | 17.4 pq | 33.2 v | 37.0 r | 55.5 c | 51.7 w | 5.6 jk | 76 ıj |
| Brooke | 22.8 q | 24.3 b | 50.3 g | 58.0 c-e | 53.1 e-g | 58.7 b | 13.3 b | 86 d |
| Challenger | 18.7 jk | 17.8 no | 39.6 t | 44.1 q | 58.8 b | 55.3 n-q | 6.5 ı | 74 jk |
| Çağlı | 19.0 ıj | 20.9 d | 42.3 r | 43.2 q | 50.8 ı-k | 53.6 u | 4.3 no | 61 m |
| Doruk | 18.9 ı-k | 20.7 de | 46.7 j | 54.7 hı | 49.4 k-n | 56.2 h-l | 7.1 h | 60 m |
| Innovator | 20.8 d | 19.8 g-j | 45.8 l | 49.2 n | 49.2 l-n | 56.2 h-l | 3.6 p | 76 ıj |
| Jelly | 18.0 l | 16.6 t | 46.3 k | 51.1 m | 49.1 l-n | 55.8 k-n | 6.6 ı | 53 op |
| Kutup | 18.6 k | 17.8 no | 51.2 f | 56.2 fg | 48.8 m-o | 54.6 rs | 5.7jk | 59 mn |
| L.O. | 19.1 hı | 19.6 ı-l | 47.1 ı | 49.2 n | 54.1 c-f | 55.6 m-o | 8.3 f | 54 o |
| Leventbey | 18.1 l | 16.6 t | 54.6 b | 62.2 b | 54.5 c-e | 57.3 de | 7.1 h | 69 l |
| Madeleine | 16.1 op | 17.0 rs | 44.7 n | 52.8 kl | 44.8 st | 54.7 rs | 4.8 m | 57 n |
| Marabel | 17.3 m | 19.7 h-k | 40.7 s | 53.0 j-l | 57.7 b | 55.6 m-o | 5.4 kl | 53 op |
| Melody | 16.1 op | 20.1 fg | 44.9 mn | 57.3 d-f | 43.8 t | 55.0 p-r | 7.6 g | 84 de |
| Muratbey | 16.3 no | 17.7 op | 39.5 t | 43.2 q | 51.2 h-j | 52.6 v | 7.1 h | 51 p |

Table 4 (continued)
Means of physical and quality traits of 38 potato genotypes in storage conditions in 2019 year.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| R.B. | 19.5 fg | 19.2 m | 52.4 e | 46.2 p | 66.3 a | 55.5 m-p | 8.3 f | 85 d |
| VR808 | 22.5 a | 21.5 c | 49.0 h | 54.9 h | 52.7 f-h | 57.4 de | 14.0 a | 91 c |
| Zirve | 21.4 b | 20.9 d | 50.0 g | 57.3 d-f | 49.9 j-m | 56.3 h-k | 10.1 d | 80 fg |
| AFAG12 | 17.2 m | 18.0 no | 43.0 q | 46.5 p | 47.9 n-q | 55.7 l-n | 3.4 p | 99 a |
| AFAG-C | 18.0 l | 21.3 c | 46.1 kl | 56.9 ef | 51.2 h-j | 56.6 f-h | 1.5 q | 81 fg |
| AFBR4 | 15.9 pq | 16.1 u | 47.0 ıj | 57.2 d-f | 47.2 pq | 55.1 o-r | 7.6 g | 96 b |
| AFHER 11 | 21.2 bc | 19.3 lm | 55.4 a | 54.7 hı | 47.0 q | 59.5 a | 6.7 ı | 59 mn |
| AFK3 | 17.8 l | 16.8 st | 44.6 n | 52.4 l | 53.5 ef | 57.0 ef | 10.8 c | 77 hı |
| AFLA20 | 19.9 e | 19.5 j-m | 46.7 j | 62.2 b | 53.6 ef | 58.1 c | 4.3 no | 84 de |
| AFLA9 | 19.8 ef | 20.7 de | 47.0 ıj | 53.2 j-l | 51.3 h-j | 56.9 e-g | 4.1 no | 52 op |
| ELAF10 | 20.8 d | 19.9 g-ı | 53.1 d | 62.0 b | 54.3 c-e | 54.4 st | 7.1 h | 80 fg |
| ELAF11 | 19.2 g-ı | 20.5 e | 42.4 r | 58.1 cd | 50.4 ı-l | 56.5 f-ı | 9.3 e | 74 jk |
| GAF4 | 18.7 jk | 21.6 c | 43.3 q | 50.7 m | 55.2 cd | 57.6 cd | 8.6 f | 72 k |
| HEAF5 | 21.2 bc | 19.4 k-m | 50.3 g | 58.6 c | 55.5 c | 55.8 k-n | 7.9 g | 54 o |
| MK2 | 15.7 q | 18.1 n | 36.8 u | 46.4 p | 45.4 rs | 54.8 q-s | 7.6 g | 72 k |
| PAG5 | 22.6 a | 20.5 e | 53.7 c | 64.7 a | 50.4 ı-l | 56.0 ı-m | 8.4 f | 85 d |
| PAG9 | 19.4 gh | 20.0 gh | 44.0 op | 45.9 p | 49.9 j-m | 54.6 rs | 4.0 o | 85 d |
| T1AG14 | 16.6 n | 20.4 ef | 43.1 q | 47.8 o | 46.7 qr | 53.9 tu | 7.2 h | 78 gh |
| T2AG13 | 18.6 k | 20.1 fg | 45.2 m | 48.0 o | 53.9 d-f | 55.9 j-m | 5.1 lm | 74 jk |
| T3AG14 | 16.3 no | 17.0 rs | 43.7 p | 55.2 gh | 44.4 st | 53.9 tu | 11.0 c | 59 mn |
| T3LA8 | 17.9 l | 19.8 g-j | 43.1 q | 53.7 ı-k | 51.6 g-ı | 57.4 de | 4.4 n | 82 ef |
| T3PO13 | 22.8 a | 24.4 b | 44.8 n | 57.0 d-f | 48.7 m-p | 56.4 g-j | 5.7 jk | 53 op |
| T7LA8 | 20.9 cd | 24.8 a | 44.1 o | 54.1 h-j | 47.9 n-q | 54.3 st | 5.8 j | 82 ef |
| Mean | 18.8 | 19.5 | 45.5 | 52.8 | 51.1 | 55.7 | 6.9 | 71 |
| $Lsd_{\text{genotype pre-storage (0.01)}}$ | 0.32 | | 0.37 | | 1.54 | | 0.38 | 2.37 |
| $Lsd_{\text{genotype post-storage (0.01)}}$ | 0.32 | | 1.14 | | 0.56 | | | |

While the leaf chips yield of tubers harvested in 2019 was 45.5 % before storage, this rate was 52.8 % after storage, and although the leaf chips yield of tubers fluctuated after storage, the general trend was to increase. Looking at the pre-storage data; While AFHER11 line was included in group (a) with 55.4 %, Agata variety represented (w) group with 32.7 %. After the storage; PAG5 line with 64.7 % was in the first group (a), Agria variety was in the last group (r) with 37.0 % (Table 4). While the leaf chips yield of tubers harvested in 2020 was 51.1 % in the analysis made before they were put into storage, this rate increased slightly by 53.9 % after storage. When the pre-storage values were examined, Konya location was in group (a) with 51.9 %, Karaman location was in group (b) with

50.2 %. After the storage, Konya location was determined with 55.0 % in group (a), and Karaman location with 52.9 % in group (b). According to genotype averages, PAG5 line was determined with 59.2 % before storage and Brooke variety (a) with 61.6 % after storage. The lowest leaf chips yield value was determined in the GAF4 line with 41.3 % before the storage and this value was in the (i) group, while it was determined on the same line with 41.2 % after the storage and was recorded in the (k) group. Although there were fluctuations, the general trend was that the yield values of leaf chips increase after storage (Table 5). In the study conducted by Kara (1996), an increase in chips yield was determined due to the decrease in storage weight losses in tuber. It was reported that the leaf chips yield of varieties with high dry matter ratios increased at that rate (Das et al., 2001). As a result of this study, the result determined as the increase in the post-storage values of dry matter ratios was in harmony with the information of these researches.

Table 5
Means of physical and quality traits of 15 potato genotypes in storage conditions in 2020 year.

| Genotypes | Ratio of Dry Matter (%) | | | Ratio of Dry Matter (%) | | | Yield of leaf chips (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-storage | | | Post-storage | | | Pre-storage | | |
| | Konya | Karaman | Mean | Konya | Karaman | Mean | Konya | Karaman | Mean |
| Agria | 20.6 g | 16.9 mn | 18.8 ef | 19.4 kl | 19.2 l | 19.3 e | 48.4 k | 42.8 m | 45.6 h |
| Brooke | 21.4 a | 23.2 a | 22.3 b | 21.8 c | 23.0 a | 22.4 a | 55.3 cd | 58.7 b | 57.0 b |
| Doruk | 24.1 b-d | 21.7 bc | 22.9 a | 22.5 b | 21.4 de | 21.9 b | 58.8 b | 50.1 hı | 54.4 c |
| Kutup | 22.3 c-e | 22.1 b | 22.2 b | 22.4 b | 21.2 e | 21.8 b | 49.5 ıj | 58.4 b | 53.9 c |
| L.O. | 17.3 lm | 20.8 d-f | 19.0 de | 19.7 k | 17.3 o | 18.5 g | 42.3 m | 48.8 jk | 45.5 h |
| Melody | 13.3 op | 15.3 p | 14.3 ı | 15.7 r | 15.9 r | 15.8 k | 54.4 de | 42.4 m | 48.4 f |
| R.B. | 19.3 no | 17.1 l-n | 18.2 g | 19.7 k | 16.5 q | 18.1 h | 49.3 ı-k | 45.9 l | 47.6 g |
| Zirve | 16.7 ı-k | 16.9 mn | 16.8 h | 17.4 o | 18.1 n | 17.8 ı | 50.0 hı | 58.0 b | 54.0 c |
| AFAG-C | 18.7 k-m | 17.8 j-l | 18.3 fg | 21.1 ef | 17.4 o | 19.3 e | 53.5 ef | 50.8 gh | 52.2 e |
| AFBR4 | 20.3 mn | 17.2 l-n | 18.7 e-g | 16.9 p | 16.7 pq | 16.8 j | 52.5 f | 52.7 f | 52.6 de |

Table 5 (continued)
Means of physical and quality traits of 15 potato genotypes in storage conditions in 2020 year.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ELAF10 | 18.3 f | 19.3 g | 18.8 ef | 21.7 cd | 20.2 ıj | 20.9 cd | 52.9 f | 53.0 f | 53.0 d |
| ELAF11 | 19.6 g-ı | 19.3 g | 19.5 cd | 20.4 h-j | 18.7 m | 19.5 e | 56.1 c | 49.8 h-j | 52.9 de |
| GAF 4 | 18.3 ef | 18.4 h-j | 18.4 fg | 20.8 fg | 20.5 g-ı | 20.7 d | 40.8 n | 41.9 m | 41.3 ı |
| PAG 5 | 21.0 lm | 19.0 gh | 20.0 c | 20.7 gh | 17.3 o | 19.0 f | 64.0 a | 54.4 de | 59.2 a |
| T7LA8 | 19.4 f | 18.7 g-ı | 19.0 de | 22.0 c | 20.1 j | 21.1 c | 51.2 g | 46.1 l | 48.7 f |
| Mean | 19.4 a | 18.9 b | 19.1 | 20.1 a | 18.9 b | 19.5 | 51.9 a | 50.2 b | 51.1 |
| Lsd genotype (0.01) = 0.53 | | | | Lsd genotype (0.01) = 0.23 | | | Lsd genotype (0.01) = 0.73 | | |
| Lsd locationx genotype (0.01) = 0.75 | | | | Lsd locationx genotype (0.01) = 0.32 | | | Lsd locationx genotype (0.01) = 1.04 | | |
| Genotypes | Yield of leaf chips (%) | | | Yield of French fries (%) | | | Yield of French fries (%) | | |
| | Post-storage | | | Pre-storage | | | Post-storage | | |
| | Konya | Karaman | Mean | Konya | Karaman | Mean | Konya | Karaman | Mean |
| Agria | 49.4 m | 42.1 o | 45.7 ı | 51.6 g | 49.7 h | 50.7 e | 60.9 b | 50.9 jk | 55.9 c |
| Brooke | 61.4 cd | 61.8 cd | 61.6 a | 52.2 g | 50.1 h | 51.1 e | 51.9 ıj | 53.2 gh | 52.6 ef |
| Doruk | 63.4 b | 56.9 gh | 60.2 bc | 48.3 ı | 53.0 f | 50.7 e | 52.7 hı | 51.9 ıj | 52.3 f |
| Kutup | 51.3 l | 58.2 fg | 54.7 e | 56.9 b | 58.0 a | 57.5 a | 56.8 d-f | 57.0 de | 56.9 b |
| L.O. | 48.6 m | 48.9 m | 48.7 h | 52.2 g | 53.0 f | 52.6 c | 51.8 ıj | 57.5 d | 54.6 d |
| Melody | 51.3 l | 55.9 hı | 53.6 f | 45.8 j | 37.6 o | 41.7 ı | 38.6 r | 37.7 r | 38.1 l |
| R.B. | 42.8 o | 46.0 n | 44.4 j | 58.3 a | 55.6 c | 57.0 a | 64.3 a | 59.3 c | 61.8 a |
| Zirve | 61.7 cd | 60.7 de | 61.2 ab | 45.2 j | 45.8 j | 45.5 h | 46.4 mn | 56.0 ef | 51.2 g |
| AFAG-C | 49.9 lm | 54.5 ı-k | 52.2 g | 51.9 g | 54.8 d | 53.3 b | 54.1 g | 52.0 ı | 53.1 e |
| AFBR4 | 62.1 b-d | 53.6 jk | 57.8 d | 48.9 ı | 44.1 k | 46.5 g | 46.8 m | 40.5 q | 43.7 j |
| ELAF10 | 62.4 bc | 57.6 g | 60.0 c | 43.5 k | 40.5 m | 42.0 ı | 48.5 l | 53.2 gh | 50.8 g |
| ELAF11 | 59.4 ef | 56.8 gh | 58.1 d | 50.4 h | 44.1 k | 47.3 f | 50.1 k | 43.7 o | 46.9 h |
| GAF 4 | 42.6 o | 39.9 p | 41.2 k | 41.4 l | 39.5 n | 40.5 j | 46.1 mn | 45.4 n | 45.7 ı |
| PAG 5 | 65.8 a | 54.9 ıj | 60.4 bc | 50.4 h | 53.9 e | 52.1 cd | 58.8 c | 55.8 f | 57.3 b |
| T7LA8 | 53.0 k | 45.2 n | 49.1 h | 55.0 cd | 48.5 ı | 51.8 d | 42.3 p | 41.7 p | 42.0 k |
| Mean | 55.0 a | 52.9 b | 53.9 | 50.1 a | 48.5 b | 49.3 | 51.3 a | 50.4 b | 50.9 |
| Lsd genotype (0.01) = 1.09 | | | | Lsd genotype (0.01) = 0.54 | | | Lsd genotype (0.01) = 0.73 | | |
| Lsd locationx genotype (0.01) = 1.54 | | | | Lsd locationx genotype (0.01) = 0.77 | | | Lsd locationx genotype (0.01) = 1.04 | | |

While the yield of French fries before storage of tubers harvested in 2019 was 51.1 %, this rate was 55.7 % after storage, and the yield of French fries after storage increased despite fluctuations. Looking at the pre-storage data; While Russet Burbank variety was in the (a) group with 66.3 %, the Melody variety represented the (t) group with 43.8 %. After the storage; AFHER11 line took the lead with 59.5 % in (a) group, while Agria was determined in the last group

(w) with 51.7 %. Although there were exceptions, the general trend was towards an increase after storage (Table 4). In the pre-storage analysis in 2020, the yield of French fries was 49.3 %, while this rate increased by 50.9 % after the storage. When the pre-storage values were examined, Konya location was ahead of Karaman location (48.5 %) with 50.1 %. After storage similarly, Konya location surpassed.

Karaman location (50.4 %) with 51.3 %. According to the genotype averages, the highest French fries yield rates were 57.5 % for Kutup variety and 57.0 % for Russet Burbank variety in pre-storage conditions. After storage, the highest French fries yield value was 61.8 % in the Russet Burbank variety. The lowest French fries yields were recorded in the GAF4 line with 40.5 % before storage, and the Melody variety with 38.1 % after storage. Although there were fluctuations, the general trend was that the yield values of French fries increased after storage (Table 5).

French fries yield is related to dry matter ratio, and genotypes with high dry matter yields are also high. In this study, French fries yield of genotypes with high dry matter content (Table 4 and Table 5) was also high. Karadoğan (1994a) reported a positive relationship between chips, French fries yields, specific gravity and dry matter, and a negative relationship between protein and fat absorption rates. It was determined that the results of this research show similarity with the results of the studies (Senol, 1970; Sanli, 2012), which reported that the yields of French fries increase in parallel as the moisture losses in the tuber decrease.

The tuber weight loss values after storage in 2019 were examined; the trial average was determined as 6.9 %. The genotype that lost the most weight after storage was VR808 variety with 14.0 %, and the least weight loss was detected in the AFAGC line with 1.5 %. Loss rates recorded above the trial average were determined in AFAG12, AFHER11, AFLA20, AFLA9, PAG9, T2AG13, T3LA8, T3PO13 and T7LA8 lines. In standard varieties; It was detected in Agria, Challenger, Çağlı, Innovator, Jelly, Kutup, Madeleine and Marabel cultivars (Table 4).

When the storage losses of tubers in 2020 were examined, the trial average was 6.7 %. According to the

locations, higher losses were detected in the Konya location (8.8 %), and almost 50 % fewer losses were detected in the Karaman location (4.7 %). According to the average of genotypes, Russet Burbank variety was determined as the highest weight loss with 10.3 %. The least weight loss was detected in the AFAGC line with 1.8 %. According to the location x genotype interactions, Konya x Brooke was the highest with 14.6 %, and Karaman x AFAGC was the interaction with the lowest weight loss with 1.5 %. AFAG-C line showed high storage resistance after both growing seasons (Table 6).

Potato tubers are living organisms that breathe, even after harvest. The high moisture content and metabolic activity of potato tubers cause weight and nutrient losses during storage. These losses occur due to respiration, transpiration and shoot growth (Burton, 1978; Gottschalk and Ezekiel, 2006). The difference in weight loss in genotypes varies with respiration, transpiration and shoot formation (Kolbe et al., 1995).

Weight changes determined as storage weight losses were found close to the findings of Kara (2004) (5.8 - 13.5%) and Okur (2008) (7.2-9.5%). The values related to storage weight losses in the study were determined to be well above the limits found by Ozcan (2019) (1.27-4.81%) and Ozturk et al. (2016) (1.32 - 2.74%).

The trial average of the first shoot formation time of tubers in 2019 was determined as 71 days. The earliest shoot forming genotype was Agata variety with 37 days, the latest shoot forming genotype was AFAG12 line with 99 days (Table 4).

When the first shoot formation time of the tubers in 2020 was examined, it was determined that while the first shoot formation time was 95 days in Karaman location, this period was 81 days for the Konya location. According to the genotype averages, the AFAGC line was determined as 113 days and classified in group (a). The earliest shooted line was ELAF10 with 55 days (Table 6).

Sprouting can be prevented by reducing the storage temperature to 2-4 °C followed by a constant temperature and 85-90 % relative humidity after harvest (Hartmans et al., 1995). However, shoot growth is inhibited in tubers stored at these temperatures for a long time. As a result, the quality of chips is negatively affected as the presence of reducing sugar increases (Kumar et al., 2007). In this study, although the first shoot formation period differed, it was parallel with the weight loss of tubers. The values determined as a result of the study were compatible with the results reported by (Kara, 2000) and (Kara, 1996).

When the quality of leaf chips before storage was examined in 2019, AFAG-C, AFBR4, AFHER11, GAF4, ELAF10, PAG9, T3AG14, T3PO13 were included in the "5" scale. Brooke, Agria, Kutup, Doruk, VR808, Zirve gave the best results in standard varieties. Only MK2 was determined as the line that cannot be used for chips, and among the standard varieties; Agata, Melody, Marabel, Madeleine were determined on a "1" scale. Except for the exceptions (AFK3, AFLA20, AFLA9, ELAF11, Çağlı, Jelly), no difference was observed in the pre- and post-storage changes (Table 7). When the leaf chips quality scale values were examined in 2020, the color scale values before and after storage were the same. Melody variety is the only genotype in the "1" scale in Konya and Karaman locations. The perfect color was detected in all genotypes except for Lady Olympia and GAF4 (Table 8). Chips quality; tuber size, shape, eye depth, specific gravity, dry matter and reducing sugar levels. These factors depend on cultural practices, environmental conditions, and genotype. However, the genetic component has the most decisive influence on inherited traits (Abong et al., 2012).

Table 6
Means of physical and quality traits of 15 potato genotypes in storage conditions in 2020 year.

| Genotypes | Storage weight loss (%) | | | The first shoot formation time (day) (kg) | | |
|---|---|---|---|---|---|---|
| | Konya | Karaman | Mean | Konya | Karaman | Mean |
| Agria | 6.6 k | 4.5 l | 5.6 hı | 77 h-j | 124 a | 100 c |
| Brooke | 14.6 a | 2.6 p | 8.6 c | 89 ef | 92 e | 90 f |
| Doruk | 11.0 c | 3.6 n | 7.3 f | 83 f-h | 111 bc | 97 cd |
| Kutup | 8.7 f | 3.0 o | 5.8 h | 81 g-ı | 116 b | 98 c |
| L.O. | 7.4 hı | 4.1 m | 5.8 h | 60 k | 103 d | 82 g |
| Melody | 6.6 k | 3.0 o | 4.8 j | 71 j | 113 bc | 92 ef |
| R.B. | 8.1 g | 12.5 b | 10.3 a | 104 d | 53 lm | 79 g |
| Zirve | 10.4 d | 4.8 l | 7.6 e | 84 fg | 117 b | 100 c |
| AFAG-C | 2.1 q | 1.5 r | 1.8 k | 116 b | 111 bc | 113 a |
| AFBR4 | 8.7 f | 2.1 q | 5.4 ı | 76 ıj | 112 bc | 94 de |
| ELAF10 | 12.5 b | 7.1 ıj | 9.8 b | 59 kl | 51 m | 55 ı |
| ELAF11 | 9.5 e | 7.0 j | 8.2 d | 62 k | 73 j | 67 h |
| GAF 4 | 10.4 d | 3.3 no | 6.8 g | 64 k | 93 e | 79 g |
| PAG 5 | 8.4 fg | 8.7 f | 8.5 c | 85 fg | 53 lm | 69 h |
| T7LA8 | 7.5 h | 2.4 pq | 5.0 j | 103 d | 108 cd | 105 b |
| Mean | 8.8 a | 4.7 b | 6.7 | 81 b | 95 a | 88 |
| $Lsd_{genotype\ (0.01)}$ = 0.23 | | | | $Lsd_{genotype\ (0.01)}$ = 3.98 | | |
| $Lsd_{locationx\ genotype\ (0.01)}$ = 0.33 | | | | $Lsd_{locationx\ genotype\ (0.01)}$ = 6.50 | | |

Table 7
Quality of leaf chips (1-5 scale)[A], quality of french fries (0-4 scale)[B], blackening (1-5 scale) [C] scale values of the study conducted in 2019*

| Varieties | A1 | A2 | B1 | B2 | C1 | C2 | Lines | A1 | A2 | B1 | B2 | C1 | C2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agata | 1 | 1 | 4 | 4 | 3 | 3 | AFAG12 | 2 | 2 | 2 | 2 | 3 | 3 |
| Agria | 5 | 5 | 0 | 0 | 5 | 5 | AFAG-C | 5 | 5 | 0 | 0 | 5 | 5 |
| Brooke | 5 | 5 | 0 | 0 | 5 | 5 | AFBR4 | 5 | 5 | 0 | 0 | 5 | 5 |
| Challenger | 4 | 4 | 1 | 1 | 3 | 3 | AFHER 11 | 5 | 5 | 0 | 0 | 3 | 3 |
| Çağlı | 2 | 4 | 4 | 3 | 5 | 5 | AFK3 | 3 | 4 | 3 | 3 | 2 | 2 |
| Doruk | 5 | 5 | 0 | 0 | 5 | 5 | AFLA20 | 3 | 4 | 3 | 3 | 4 | 4 |
| Innovator | 4 | 4 | 0 | 0 | 3 | 3 | AFLA9 | 3 | 4 | 3 | 3 | 5 | 5 |
| Jelly | 3 | 4 | 3 | 3 | 2 | 2 | ELAF10 | 5 | 5 | 0 | 0 | 5 | 5 |
| Kutup | 5 | 5 | 0 | 0 | 5 | 5 | ELAF11 | 3 | 4 | 2 | 2 | 5 | 5 |
| L.O. | 4 | 4 | 1 | 1 | 3 | 3 | GAF4 | 5 | 5 | 2 | 2 | 3 | 3 |
| Leventbey | 3 | 3 | 3 | 3 | 3 | 3 | HEAF5 | 4 | 4 | 1 | 1 | 3 | 3 |
| Madeleine | 1 | 1 | 4 | 4 | 3 | 3 | MK2 | 1 | 1 | 4 | 4 | 3 | 3 |
| Marabel | 1 | 1 | 4 | 4 | 3 | 3 | PAG5 | 4 | 4 | 1 | 1 | 5 | 5 |
| Melody | 1 | 1 | 4 | 4 | 3 | 3 | PAG9 | 5 | 5 | 0 | 0 | 4 | 4 |
| Muratbey | 2 | 2 | 3 | 3 | 3 | 3 | T1AG14 | 4 | 4 | 1 | 1 | 3 | 3 |
| R.B. | 4 | 4 | 0 | 0 | 4 | 4 | T2AG13 | 3 | 3 | 3 | 3 | 5 | 5 |
| Vr808 | 5 | 5 | 0 | 0 | 3 | 3 | T3AG14 | 5 | 5 | 0 | 0 | 2 | 2 |
| Zirve | 5 | 5 | 0 | 0 | 5 | 5 | T3LA8 | 2 | 2 | 2 | 2 | 4 | 4 |
| | | | | | | | T3PO13 | 5 | 5 | 0 | 0 | 4 | 4 |
| | | | | | | | T7LA8 | 4 | 4 | 1 | 1 | 5 | 5 |

*1: Pre-storage; 2: Post-storage

Depending on the variety, potatoes begin to accumulate reducing sugar, which gives a sweet taste during and after storage and causes an undesirable brown color in chips and french fries. These reducing sugars have a negative effect on the technological processing of potatoes (Schwimmer et al., 1957). When the colors of the chips are evaluated, the chips colors of the varieties with low, reducing sugar content give better results (Das et al., 2001).

The potato used industrially should have a high yield of French fries (fried potatoes) and chips. In addition, the fact that they absorb less oil during frying is a desirable feature in terms of both health and low cost. The most important feature is the color of chips and French fries. Chips and fried potatoes should show a golden yellow and uniform color (Karadogan, 1994b). This study determined the desired color scale values for all selected lines in 2020.

Table 8
Quality of leaf chips (1-5 scale)[A], quality of french fries (0-4 scale)[B], blackening (1-5 scale) [C] scale values of the study conducted in 2020*

| Genotypes | A1 | | A2 | | B1 | | B2 | | C1 | | C2 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | a | b | a | b | a | b | a | b | a | b | a | b |
| Agria | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 |
| Brooke | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 |
| Doruk | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 |
| Kutup | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 |
| L.O. | 4 | 4 | 4 | 4 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 |
| Melody | 1 | 1 | 1 | 1 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 |
| R.B. | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 4 | 3 | 4 | 3 |
| Zirve | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 |
| AFAG-C | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 |
| AFBR4 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 4 | 5 | 4 | 5 |
| ELAF10 | 5 | 5 | 5 | 5 | 1 | 1 | 1 | 1 | 5 | 5 | 5 | 5 |
| ELAF11 | 5 | 5 | 5 | 5 | 1 | 1 | 1 | 1 | 5 | 5 | 5 | 5 |
| GAF4 | 4 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 5 | 5 | 5 | 5 |
| PAG5 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 |
| T7LA8 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 |

*1: Pre-storage; 2: Post-storage; a: Konya, b: Karaman

When the color scale values of French fries before the storage were examined in 2019, AFAG-C, AFBR4, AFHER 11, ELAF10, PAG9, T3AG14, and T3PO13 were included in the "0" scale. In terms of standard cultivars, Brooke, Agria, Innovator, Kutup, Russet Burbank, Doruk, VR808, Zirve varieties gave the best results. Only MK2 was determined as the line that cannot

be French fries. Among the standard varieties; Agata, Çağlı, Melody, Marabel, and Madeleine were determined on the 4 scale (Table 7).

When the color scale values of French fries before storage were examined in 2020, 0 and 1 values, which are determined as very good and good scale definitions, are seen in all genotypes except for Melody variety. Color values did not change after storage (Table 8).

The amount of starch in the tuber affects the color of chips and French fries. Sugar, amino acids and other compounds in potato slices exposed to high temperatures during the frying process combine, causing a dark color and a burnt taste. Potato varieties with high sugar content cause consumers not to prefer them because of this color status during frying (Stark, 2003). The amount of reducing sugar and phenol content in the tuber must be low so that the chips and French fries do not turn brown and have a bitter taste (Wiltshire and Cobb, 1996; Wang-Pruski and Nowak, 2004). Browning after frying is caused by reducing sugar content and the interaction with the amino acid sucrose (Shallenberger et al., 1959). The type of oil used while frying, the frying temperature, the frying time, and the type of frying affect the color change (Pringle et al., 2009). The MK2 line was subjected to negative selection, and the breeding lines in the "0" scale were examined in terms of other breeding criteria.

When the pre-storage blackening color scale values were examined in 2019, the genotypes on the 5 scale were determined as AFAG-C, AFBR4, AFLA9, Agria, Brooke, Çağlı, Doruk, ELAF10, ELAF11, Kutup, Zirve, T7LA8, T2AG13, PAG5. No change was observed after storage, either (Table 7). When the color scale values of the year 2020 were examined, it was observed that almost all genotypes gave a positive result in darkening, and no change was detected after storage. The Russet Burbank variety detected more significant blackening than the others (Table 8).

## 4. Coclusion

The healthy storage of tubers is as important as the cultivation of potatoes. For this reason, the main objectives are to prevent the development of shoots, adjust the storage temperatures and have the least loss of physical and quality properties of the tubers in the storage. In this study, significant changes occurred in all values compared to the pre-storage parameters of the tubers, which were exposed to excessive shoot growth and moisture loss. Dry matter content was in parallel with the yield of leaf chips and French fries, increasing after storage. As a result of the study, T7LA8, PAG5 and GAF4 lines with high ratio of dry matter, yields of chips and French fries were determined as promising lines.

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**Research Article**

# The Effects of Iron Application Foliarly at Different Times and Amounts on Agricultural Characteristics in Some Peanut Varieties

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**ABSTRACT**

This study aimed to determine the effects of treated iron doses on agricultural characteristics by applying foliar in some peanut varieties (NC-7 and Sultan). It was conducted at different times (flowering period and pod formation period) and doses (control, 400 kg da $^{-1}$, 500 kg da $^{-1}$, 600 kg da$^{-1}$) in the farmer's field in the Göçmenler district in the Hardallık village of Kadirli, Osmaniye, in April and September of 2020. The study was arranged in a "Split-Split Plots Experiment Desing" with three replications, and varieties to the main parcels, treatment time to the sub-parcels, iron doses to the sub-sub-parcels, were treated. In the study, variety, dose, variety x dose, time x dose, variety x time x dose interactions were statistically important in pod yield. In terms of number of pod per plant, 100 pod weight, 100 seed weight; variety x dose, time x dose, variety x time x dose interactions are important, however in the seed ratio, these interactions turned out to be statistically insignificant except variety. According to the results obtained, the highest pod yield was obtained as 521.1 kg da$^{-1}$ from treatments of Sultan varieties in terms of varieties; it was obtained as 544.5 kg da $^{-1}$ from pod formation period and 400 kg da $^{-1}$ dose in terms of variety x time interaction and it was obtained as 512.6 kg da $^{-1}$ from 400 kg da$^{-1}$treatment in terms of dose. As a result; for both periods to achieve high pod yield in peanut cultivation, 400 kg da $^{-1}$ iron dose treatment and Sultan variety in Osmaniye conditions can be recommended.

## 1. Introduction

Although iron is the most abundant nutrient element in the soil, iron deficiency is an important nutritional problem in agricultural areas, especially in areas where calcareous peanuts are grown (Sing, 2004; Sing et al., 2003). Although the total amount of iron in the soil is high, to the effect of the limestone and $HCO_3$ in the soil, the amount of iron useful for the plant decreases. Therefore iron deficiency in plants is observed more often and commonly (Lindsay and Schwab, 1982). It is estimated that between 30 % and 50 % of the planted areas in the world have iron deficiency (Çakmak, 2002). It has been determined that this situation is not different in soils in agricultural areas in Turkey and has reached 27 % (Eyüpoğlu et al., 1995). The microelement deficiency of plant cultivation and the iron deficiency is widely seen in soil with high limestone and low organic material (Zengin and Gezgin, 2013). Iron deficiency caused by limestone reduces the chlorophyll content in the young leaves of plants and causes chlorosis (Marschner, 1995; Bashir et al., 2013).

In the world, the planting area of peanuts in 2019 was 29.596.969 hectare, and the production of 48.756.790 tons was actualized. Such countries as China, India, Nigeria, USA are leading regarding the production of peanuts. Its production is widespread in countries such as Sudan, Myanmar, Senegal. In our country, in the area of 42.218 hectare, 169.328 tons of production were actualized in the production season of 2019 and the pod yield per decare was recorded as 401 kg (Anonymous,2021a). Besides Adana and Osmaniye are the most peanut producing provinces, peanuts being also produced in our provinces such as Antalya, Aydın, Kahramanmaraş, Mersin, Hatay (Anonymous, 2021b).

Selection of varieties and treated cultural practices are among the factors that will directly affect the productivity obtained from the unit of area (Arıoğlu et al., 2016). The effectiveness of iron is different according to the species and varieties of plants, even it is different in

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the lower varieties of the same variety. It is known that peanuts and fruit trees are prone and sensitive to iron deficiency (Rombolà and Tagliavini, 2006; Pestana et al., 2012).

In order to increase the yield and quality of peanuts taken per unit area, iron deficiencies must be eliminated by using proper ferrous fertilizer as of the bearing of of the cultivated soil characteristics (limestone, soil reaction and organic matter etc.). Sing (2004) reported that the use of iron sulfate is ineffective in eliminating iron deficiency in soils with limestone, alkaline reaction and low organic matter. For this reason, Fe-EDDHA is used to aid in eliminating the iron deficiency of the plant (Pestana et al., 2003). In addition to its ability to retain iron in calcareous and alkaline soils, Fe-EDDHA can be more effective in eliminating iron deficiency in the plants by binding Fe in plant roots (Lucena, 2003; Rodríguez-Lucena et al., 2010).

This study aimed to determine the effects of treated iron doses on agricultural characteristics by applying foliar in some peanut varieties (NC-7 and Sultan) often used in Osmaniye conditions.

## 2. Materials and Methods

This study was carried out in the farmer's field conditions in the Göçmenler district in the Hardallık village of Kadirli, Osmaniye, in 2020. The soil in which the field trial was established had a neutral reaction (pH=6.87), excessive calcareous (25.8 %), a moderate level of organic matter (2.38 %), a level of salt that could not cause problems in plant development (390 μS $cm^{-1}$) and a clayed tin (CL) structure. Phytosanitary contents such as: Ca (5921 mg $kg^{-1}$), Mg (555 mg $kg^{-1}$) and Cu (2.21 mg $kg^{-1}$) were excessive, while the phytosanitary contents were in sufficient quantities, such as P (31.33 mg $kg^{-1}$), B (1.43 mg $kg^{-1}$), Zn (1.06 mg $kg^{-1}$) and Mn (8.80 mg $kg^{-1)}$ and K (137 mg $kg^{-1}$) level was intermediate, Fe (1.93 mg $kg^{-1}$) level was low.

Considering the peanut cultivation period, the average temperature of the trial area changed between 18.1 and 28.6°C in 2020 and 18.3 to 29.1°C in the long years average. The total rainfall was 115.6 mm in 2020 and 123.7 mm on the long-year average during the trial period.However, due to insufficient total rainfall, the water required was met by irrigation.

The study was arranged in a "Split-Split Plots Experiment Desing" with three replications. The most cultivated "NC-7 and Sultan" peanut varieties were used in the area, and both varieties were included in the Virginia group and were in the horizontal-semi form. The NC-7 variety was a variety of US origin, BATEM registered it in 1991. As for the Sultan variety, it was registered by the Field Crops of the Faculty of Agriculture of Cukurova University (Irmak et al, 2012; Arioglu et al., 2016). In the trial, as the chemical base fertilizer prior to planting, 15 kg $da^{-1}$ 12-12-12+% 23 $SO_3$+% 10 organic matter and orgamineral fertilizer, 15 kg da $^{-1}$ 9-21-0 + Zn + 5% $SO_3$ + 1% Zn + 15% organic matter + 10% humic and fulvic acid were treated by mixing them into the soil. With the planting, 3 kg $^{-1}$ was treated from the 16-40-0 + 5% $SO_3$ + 2% Zn + 2% Mg contained fertilizer and on the date of 1 July 2020 ammonium sulfate (21 % N) 25 kg da $^{-1}$ was treated as the top fertilizer. It was treated with Fe EDDHA (6 % Fe) during the 50 % flowering period (3 July 2020) and pod formation period (19 August 2020) periods as it provides 400 g da $^{-1}$, 500 g da $^{-1}$ and 600 g da $^{-1}$ pure Fe at the trial (Kur et al., 2018).

After the silage corn harvest, the tillage was deep-processed with a plow in the fall and abandoned for the winter. Afterward, the soil was slightly processed with a cultivator again in April; then, it was harrowed and made ready for the planting. Each trial parcel was formed from four rows with a width of 2.8 m and a length of 3.0 m. The area of each parcel was arranged as 8.4 $m^2$ and there were 1-meter gaps between the parcels and the replications. In the trial, each parcel was arranged to be 4 rows; these rows specified the marker plantation were manually carried out with 12 cm over these rows and 70 cm among the rows on 12 April 2020.Weed control was carried out both mechanically and with herbicides. Disinfestation was carried out twice for leafworm, aphid and leaf spot disease. It was harvested by manually on 27 September 2020. After the edge effects of the parcels were discarded, 0.5 m was removed from both sides of the middle two rows and the remaining 2 m was harvested manually.

Their pod yields were recorded by weighing each parcel separately and their pod yields per decare were determined by calculating. Other data was determined in plants that will represent each parcel after the pods have been dried as; the number of pod per plant (piece), 100 pod weights (g), 100 seed weights (g), seed ratio (%).

The data was analyzed using technique of analysis of variance (JUMP) and treatment means were separated by Least Significant Differences (LSD) at 1 % probability level by using MSTAT-C as described by Nissen (1989).

## 3. Results and Discussion

Average values, groups and Lsd values regarding the number of pod per plant (quantity), 100 pod weight (g), 100 seed weight (g), pod yield (kg $da^{-1}$), seed ratio (%) were given in Table 2 and Table 3. The analysis of variance considering these characteristics is given in Table 1.

As could be seen from the examination of Table 2, the differences between the variety, VxD, TxD, VxTxD in terms of the number of pod per plant were found to be statistically significant at the 1% significance level, and the lowest number of pod was NC-7 variety with 21.8 $plants^{-1}$, the highest number of pod was Sultan variety with 26.4 $plants^{-1}$. According to the treatment times, doses and VxT interactions, no statistical level difference was obtained between the values. In VxD interactions, the lowest number of pod was the NC-7 variety with 20.2 $plants^{-1}$ and 21.6 $plants^{-1}$except for $D_3$ of the

NC-7 variety. The highest number of pod was obtained from $D_2$ treatment of the ile Sultan variety with 28.4 plants$^{-1}$. In TxD interactions, the highest pod yield was determined as 25.8 plants$^{-1}$ with $T_2xD_2$ interaction and the lowest pod yield was determined as 22.8 plants$^{-1}$ with $T_1xD_2$ interaction. When looking at the VxTxD interactions, the lowest number of pod was obtained as 18.8 plants$^{-1}$ from $V_1xT_1xD_2$ interaction while the highest number of pod was recorded as 30.0 plants$^{-1}$ from the interaction of $V_2xT_2xD_2$. Our research was in harmony with the findings of many studies as increasing Fe doses increases the number of pod per plant (Guvercin, 2009; Kur et al., 2018).

Table 1
Results of variance analysis of the agricultural characteristics in the study conducted in 2020

| Source of Variation | df | Means square | | | | |
|---|---|---|---|---|---|---|
| | | The number of pod per plant (quantity) | 100 pod weight (g) | 100 seed weight (g) | Pod yield (kg da$^{-1}$) | Seed ratio (%) |
| Replication | 2 | 2.2 | 29.3 | 2.7 | 1903.1 | 0.9 |
| Variety (V) | 1 | 245.7** | 141.5* | 1.5 | 74481.8* | 194.8* |
| Error-1 | 2 | 0.5 | 5.5 | 4.0 | 2110.5 | 10.3 |
| Time (T) | 1 | 6.6 | 1.1 | 3.1 | 294.0 | 0.6 |
| V x T | 1 | 0.3 | 24.9 | 1.0 | 1732.8 | 1.2 |
| Error-2 | 2 | 8.0 | 19.7 | 3.8 | 298.5 | 8.4 |
| Doses (D) | 3 | 6.4 | 24.7 | 1.5 | 8051.7** | 0.4 |
| V x D | 3 | 26.1** | 264.1** | 9.7** | 9042.2** | 2.0 |
| T X D | 3 | 8.6* | 115.3** | 12.1** | 8948.7** | 4.0 |
| V x T x D | 3 | 15.8** | 97.9** | 6.2* | 8541.5** | 4.5 |
| Error-3 | 26 | 2.4 | 24.9 | 1.7 | 895.6 | 3.1 |

*P < 0.05, **P < 0.01

Regarding 100 pod weight, differences between treatments regarding V, V x T, T x D, V x T x D interactions were determined as statistically significant at a significance level of 1% (Table 1). When looking at the variety averages, the highest 100 pod weight was NC-7 variety with 197.4 g, while the lowest 100 pod weight was obtained from Sultan variety with 194.0 g. According to the treatment times, doses and VxT interactions, no statistical level difference was obtained between the values. In VxD interactions, the lowest 100 pod weight was determined in the $V_2xD_0$ interaction with 186.8 g. The highest 100 pod weight were obtained as 200.5 g and 200.2 g respectively from $V_1xD_0$, $V_2xD_3$ interactions. In TxD interactions, the highest 100 pod weight was determined as 201.8 g in $T_2xD_2$ interaction, the lowest 100 pod weight were determined as 192.2 g and 192.6 g respectively in $T_1xD_2$ and $T_2xD_0$ interactions. When looking at the VxTxD interactions, the lowest 100 pod weight was obtained as 186.5 g from $V_2xT_1xD_0$interaction while the highest 100 pod weight was recorded as 206.2 g from $V_2xT_1xD_3$ interaction (Table 2). Güvercin (2009) reported that NC-7 variety obtained the highest 100 pod weights in $Fe_2$ treatments (202 g) in the first year, and NC-7 variety was detected with 166 g in the same dose. When looking at the varieties in general, the dose of $Fe_1$ was found to be lower than the treatments of $Fe_0$ and $Fe_2$ in the study. However, taking the NC-7 variety into account, the findings of this study of the 100 pod weight increases in Fe doses according to the control were similar to our study.

In terms of the 100 seed weight, the differences between the values in the V x D, T x D interactions were statistically significant at 1 % significance level, and in the V x T x D interaction, the differences between values were statistically significant at 5 % significance level. According to the varieties, treatment times, doses and VxT interactions, no difference was obtained at the statistical level between the values (Table 1). In VxD interactions, the lowest 100 seed weight was detected as 85.7 g in the interaction of $V_2xD_0$.The highest 100 seed weight was obtained as 88.3 g and 88.2 g respectively from the interactions of $V_1xD_0$ and $V_2xD_3$. In TxD interactions, the highest 100 seed weight were determined as 88.3 g, 88.0 g, 88.0 g, 87.4 g respectively from $T_1xD_1$, $T_2xD_2$, $T_1xD_3$ and $T_2xD_0$; the lowest 100 seed weight was determined as 85.2 g in the interaction of $T_2xD_1$. When looking at the VxTxD interactions, the lowest 100 seed weight was obtained as 84.9 g and 85.0 g, respectively from $V_2xT_1xD_0$ and $V_2xT_2xD_1$ interactions while the highest 100 seed weight was recorded as 89.9 g in the interaction of $V_2xT_1xD_3$ (Table 2). In the studies conducted, they reported that increasing Fe doses increased the 100 seed weight. Our study was within limits determined by the researchers (Irmak et al., 2012; Boydak et al., 2019).

Table 2
Average values for agricultural characteristics of Fe applications applied at different times and doses in peanuts-1

| | | The Number of Pod Per Plant (quantity) | | | | |
|---|---|---|---|---|---|---|
| | | Fe Dozları | | | | |
| Variety (V) | Time (T) | $D_0$ Kontrol | $D_1$ 400kg da$^{-1}$ | $D_2$ 500 kg da$^{-1}$ | $D_3$ 600 kg da$^{-1}$ | Mean |
| $V_1$ | Flowering ($T_1$) | 21.4 fgh | 23.7 cdef | 18.8 h | 22.5 defg | 21.6 |
| | Pod formation ($T_2$) | 21.8 efgh | 19.5 gh | 21.6 efgh | 25.8 bcd | 22.2 |
| Mean | | 21.6 d | 21.6 d | 20.2 d | 24.2 c | 21.8 b[1] |
| $V_2$ | Flowering ($T_1$) | 25.0 bcde | 25.7 bcd | 26.9 abc | 26.2 bc | 26.0 |
| | Pod formation ($T_2$) | 24.4 cdef | 28.0 ab | 30.0 a | 25.0 bcde | 26.9 |
| Mean | | 24.7 bc | 26.9 ab | 28.4 a | 25.6 bc | 26.4a |
| T x D | Flowering ($T_1$) | 23.2 cd | 24.7 abc | 22.8 d | 24.4abcd | 23.8 |
| | Pod formation ($T_2$) | 23.1 cd | 23.7 bcd | 25.8 a | 25.4 ab | 24.5 |
| Mean | | 23.2 | 24.2 | 24.3 | 24.9 | |
| LSD $_{VXD\ (0.01)}$: 2.48; LSD $_{TXD\ (0.05)}$:1.83; LSD $_{VXTXD\ (0.01)}$:3.51 | | | | | | |
| | | 100 Pod Weight (g) | | | | |
| | | Fe Dozları | | | | |
| Variety (V) | Time (T) | $D_0$ Kontrol | $D_1$ 400kg da$^{-1}$ | $D_2$ 500 kg da$^{-1}$ | $D_3$ 600 kg da$^{-1}$ | Mean |
| $V_1$ | Flowering ($T_1$) | 202.7 ab | 200.8 abc | 194.3 bcde | 188.2 de | 196.5 |
| | Pod formation ($T_2$) | 198.3 abcd | 198.2 abcd | 201.2 abc | 195.3 abcde | 198.3 |
| Mean | | 200.5 a | 199.5 ab | 197.8 ab | 191.8 bc | 197.4 a |
| $V_2$ | Flowering ($T_1$) | 186.5 e | 195.2 abcde | 190.2 cde | 206.2 a | 194.5 |
| | Pod formation ($T_2$) | 187.0 de | 190.0 cde | 202.3 ab | 194.2 bcde | 193.4 |
| Mean | | 186.8 c | 192.6 abc | 196.2 ab | 200.2 a | 194.0 b |
| T x D | Flowering ($T_1$) | 194.6 ab | 198.0 ab | 192.2 b | 197.2 ab | 195.6 |
| | Pod formation ($T_2$) | 192.6 b | 194.1 ab | 201.8 a | 194.8 ab | 195.9 |
| Mean | | 193.6 | 196.0 | 197.0 | 196.0 | |
| LSD $_{VXD\ (0.01)}$: 8.01; LSD $_{TXD\ (0.01)}$: 8.01; LSD $_{VXTXD\ (0.01)}$: 11.33 | | | | | | |
| | | 100 Seed Weight (g) | | | | |
| | | Fe Dozları | | | | |
| Variety (V) | Time (T) | $D_0$ Kontrol | $D_1$ 400kg da$^{-1}$ | $D_2$ 500 kg da$^{-1}$ | $D_3$ 600 kg da$^{-1}$ | Mean |
| $V_1$ | Flowering ($T_1$) | 88.3 abc | 89.1 ab | 86.1 def | 86.2 cdef | 87.4 |
| | Pod formation ($T_2$) | 88.3 abc | 85.3 ef | 87.7 bcd | 87.6 bcd | 87.2 |
| Mean | | 88.3 a | 87.2 ab | 86.9 ab | 86.9 ab | 87.3 |
| $V_2$ | Flowering ($T_1$) | 84.9 f | 87.6 bcd | 87.2 bcde | 89.9 a | 87.7 |
| | Pod formation ($T_2$) | 86.4 cdef | 85.0 f | 88.3 abc | 86.6 cdef | 86.9 |
| Mean | | 85.7 b | 86.3 ab | 87.7 ab | 88.2 a | 87.3 |
| T x D | Flowering ($T_1$) | 86.6 ab | 88.3 a | 86.7 ab | 88.0 a | 87.5 |
| | Pod formation ($T_2$) | 87.4 a | 85.2 b | 88.0 a | 87.1 ab | 87.1 |
| Mean | | 87.0 | 86.8 | 87.3 | 87.6 | |
| LSD $_{VXD\ (0.01)}$: 2.90; LSD $_{TXD\ (0.01)}$: 2.90; LSD $_{VXTXD\ (0.05)}$: 2.19 | | | | | | |

1: There are no statistical differences between means with the same letters. $V_1$: NC-7; $V_2$: Sultan

Table 3
Average values for agricultural characteristics of Fe applications applied at different times and doses in peanuts-2

| | | Pod Yield (kg da$^{-1}$) | | | | |
|---|---|---|---|---|---|---|
| | | Fe Dozları | | | | |
| Variety (V) | Time (T) | $D_0$ Kontrol | $D_1$ 400kg da$^{-1}$ | $D_2$ 500 kg da$^{-1}$ | $D_3$ 600 kg da$^{-1}$ | Mean |
| $V_1$ | Flowering ($T_1$) | 419.0 fg | 523.3 abc | 330.9 h | 462.1 cdefg | 433.9 |
| | Pod formation ($T_2$) | 438.6 efg | 397.9 gh | 452.8 defg | 514.0 abcd | 450.8 |
| Mean | | 428.8 de | 460.6 cd | 391.9 e | 488.1 bc | 442.3 b |
| $V_2$ | Flowering ($T_1$) | 487.9 bcde | 565.7 a | 521.7 abc | 523.4 abc | 524.7 |
| | Pod formation ($T_2$) | 493.2 bcde | 563.6 a | 538.6 ab | 475.0 bcdef | 517.6 |
| Mean | | 490.5 bc | 564.7 a | 530.1 ab | 499.2 bc | 521.1 a |
| T x D | Flowering ($T_1$) | 453.5 bc | 544.5 a | 426.3 c | 492.8 b | 479.3 |
| | Pod formation ($T_2$) | 465.9 bc | 480.7 b | 495.7 b | 494.5 b | 484.2 |
| Mean | | 459.7 b | 512.6 a | 461.0 b | 493.6 ab | |
| LSD $_{D\ (0.01)}$: 33.95; LSD $_{VXD\ (0.01)}$: 48.01; LSD $_{TXD\ (0.01)}$: 48.01; LSD $_{VXTXD\ (0.01)}$:67.90 | | | | | | |
| | | Seed Ratio (%) | | | | |
| | | Fe Dozları | | | | |
| Variety (V) | Time (T) | $D_0$ Kontrol | $D_1$ 400kg da$^{-1}$ | $D_2$ 500 kg da$^{-1}$ | $D_3$ 600 kg da$^{-1}$ | Mean |
| $V_1$ | Flowering ($T_1$) | 76.4 | 76.1 | 76.0 | 75.2 | 75.9 |
| | Pod formation ($T_2$) | 77.5 | 76.0 | 75.7 | 76.8 | 76.5 |
| Mean | | 77.0 | 76.1 | 75.9 | 76.0 | 76.2a[1] |
| $V_2$ | Flowering ($T_1$) | 71.8 | 73.3 | 71.3 | 72.5 | 72.2 |
| | Pod formation ($T_2$) | 71.9 | 70.5 | 73.9 | 72.3 | 72.1 |
| Mean | | 71.8 | 71.9 | 72.6 | 72.4 | 72.2 b |
| T x D | Flowering ($T_1$) | 74.1 | 74.7 | 73.7 | 73.9 | 74.1 |
| | Pod formation ($T_2$) | 74.7 | 73.2 | 74.8 | 74.5 | 74.3 |
| Mean | | 74.4 | 74.0 | 74.3 | 74.2 | |

1: There are no statistical differences between means with the same letters.

It determined that the differences between varieties in terms of pod yield were statistically significant at 5 % significance level, and the differences between the pod yield in terms of V x D, T x D, V x T x D interactions were statistically significant at 1 % significance level (Table 1). When the varieties were examined, the highest pod yield was recorded in the Sultan variety with 521.1 kg da$^{-1}$ and the lowest pod yield was recorded from the NC-7 variety with 442.3 kg da$^{-1}$. Statistical significance could not be determined between the values obtained in terms of treatment times and VxT interactions. When the doses were examined, the highest pod yield was recorded in the $D_1$ dose with 512.6 kg da$^{-1}$ and the lowest pod yield was recorded as 459.7 kg da$^{-1}$ and 461.0 kg da$^{-1}$ in the doses of $D_0$ and $D_1$ respectively. In VxD interactions, the lowest pod yield was obtained as 391.9 kg da$^{-1}$ in the interactions of $V_1xD_2$ and the highest pod yield was obtained as 564.7 kg da$^{-1}$ in $V_2xD_1$interaction. In TxD interactions, the highest pod yield was determined as 544.5 kg da$^{-1}$ in $T_1xD_1$ and the lowest pod yield was determined as 426.3 kg da$^{-1}$ in $T_1xD_2$. When looking at VxTxD interactions, the lowest pod yield as 330.9 kg/da in $V_1xT_1xD_2$, while the highest pod yield was recorded as 565.7 kg da$^{-1}$ and 563.6 kg da$^{-1}$, respectively in the interactions of $V_2xT_1xD_2$, $V_2xT_1xD_2$ (Table 3).

In many previous studies, it was noted that Fe treatments increase pod yield. Irmak et al. (2012) used NC-7 and ÇOM varieties were materials in their Fe treatments from soil and leaves in the peanut study conducted in 2006-2007. In the study, Fe treatments were conducted in the doses of 0, 10, 20, 40 kg ha$^{-1}$ from the soil and after twenty days, they were conducted in the doses of 0.1, 2.3 kg ha$^{-1}$ from the leaf. In the NC-7 variety, they obtained the highest pod yield in 10 kg ha$^{-1}$ Fe dose (484.8 kg da$^{-1}$) treated from the soil, and a significant increase was recorded according to the control (441.7 kg da$^{-1}$). Also, the same increase was recorded in the ÇOM variety. In foliar fertilization, the highest pod yield was carried out in 2 kg ha$^{-1}$ Fe dose in the ÇOM variety (603.0 kg da$^{-1}$). In the study, it was found that pod yield and 100 seed weight increased significantly with increasing Fe doses, but the doses were ineffective in ratio of protein and oil.

The study was conducted to determine the effects of Fe treatments in different periods and doses (10 different combinations and periods) on yield and quality components in the NC-7 varieties in Kahramanmaraş conditions in 2018 year by Kür et al. (2018). These researchers reported that pod yield increased in increasing Fe doses. The highest pod yield was determined 300 kg da$^{-1}$ flowering period + 300 kg da $^{-1}$ pod formation period (420.7 kg da$^{-1}$) and a significant increase occurred according to control (360.6 kg da$^{-1}$). the lowest pod yield was found 500 kg da$^{-1}$ pod formation period (314.8 kg da$^{-1}$) and 200 kg da$^{-1}$ flowering period + 200 kg da$^{-1}$ pod formation period (317.5 kg da$^{-1}$).

The study was carried out to determine the effects of different quantities of Fe (0, 1, 2, 4 kg da$^{-1}$) and Zn (0, 1, 2, 4 kg da$^{-1}$) doses on yield and yield components of NC-7 variety in 2017 by Boydak et al. (2019). The researchers stated that pod yield increased significantly according to control. The lowest pod yield was determined at the control and the Fe dose of 1 kg da$^{-1}$ (377.1 and 385.1 kg da$^{-1}$ respectively), while the highest pod yield was recorded at the Fe dose of 4 kg da$^{-1}$ (547.4 kg da$^{-1}$). The data obtained from the studies were in harmony with our research related to pod yield.

For the seed ratio, the differences between the values in terms of varieties were statistically significant at the significance level of 5% (Table 1). The highest seed ratio was found in the NC-7 variety with 76.2 %, and the lowest seed ratio was found in the Sultan variety with 72.2 % (Table 3). Pod yield per decare has a positive and important relationship with the number of pod per plant and seed ratio (Arioglu et al., 2016). High seed ratio is one of the reasons for preference of institutions that purchase peanuts because it increases product efficiency. According to the variety and environmental conditions, it can also vary between 60 % and 80 % (Arioglu, 2007).

The study was conducted to determine the yield and quality parameters of 6 different types of peanuts in Niğde conditions in 2014 by Aytekin and Caliskan (2016). The researchers reported that the highest seed ratio was recorded in the NC-7 variety with 70.1 %.

Kurt et al. (2016) reported that the seed ratio in NC-7 variety was recorded as 71.45 % and the Sultan variety was recorded as 59.61 % in Cukurova conditions between the years of 2013 and 2014.

Kur et al. (2018) stated that statistical significance was not determined between averages of the seed ratio, the number of pod per plant (quantity), 100 pod weight, the oil and the protein ratios. However, they reported that the number of pod per plant values between treatments at the same doses was statistically significant. Our study was in harmony with the seed ratio values of these studies

## 4. Coclusion

This study was conducted in the Osmaniye conditions, it was found that the interactions between variety, dose, variety x dose, time x dose, variety x time x dose interactions were statistically important regarding the pod yield. The number of pod per plant, 100 pod weight, 100 seed weight; varietyxdose, timexdose, varietyxtimexdose interactions were important. However, the seed ratio regarding these interactions was statistically insignificant. The highest pod yield was obtained from the Sultan variety with 521.1 kg da$^{-1}$ in terms of varieties, it was obtained from the pod formation period and 400 kg da$^{-1}$ dose with 544.5 kg da$^{-1}$ in terms of varietyxtime interactions, and it was obtained from 400 kg da$^{-1}$ treatment with 512.6 kg da$^{-1}$. in terms of dose. In conclusion, the Fe treatments were the significant influence for high pod yield and yield components in the cultivation of peanuts. However, there was no doubt that

multi-year studies in different locations, treatment times, doses, and treated varieties can achieve more precise and ultimate results.

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# Molecular Characterization of Thripidae (Thysanoptera) Species in Karaman, Konya and Mersin (Turkey)

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**ABSTRACT**

Specimens of Thripidae (Thysanoptera) species collected from Konya, Karaman and Mersin (2015-2017) were studied through molecular analyses as a part of preliminary attempts to establish a barcoding system for Thysanoptera in Turkey. The analyses included 23 species namely; *Chirothrips kurdistanus* zur Strassen, *Chirothrips manicatus* Haliday, *Frankliniella intonsa* (Trybom), *Frankliniella occidentalis* (Pergande), *Frankliniella tenuicornis* (Uzel), *Limothrips angulicornis* Jablanowski, *Odontothrips confusus* Priesner, *Odontothrips dorycnii* Priesner, *Oxythrips ajugae* Uzel, *Taeniothrips inconsequens* (Uzel), *Tenothrips anatolicus* (Priesner), *Tenothrips discolor* (Karny), *Tenothrips frici* (Uzel), *Thermothrips mohelensis* Pelikan, *Thrips angusticeps* Uzel, *Thrips atratus* Haliday, *Thrips italicus* Bagnall, *Thrips linarius* Uzel, *Thrips major* Uzel, *Thrips meridionalis* (Priesner), *Thrips physapus* Linnaeus, *Thrips tabaci* Lindeman and *Thrips trehernei* Priesner which were detected in various cultivated plants and weeds. The phylogenetic positions of the 9-genera, with few exceptions, to form their own clades by the 18S Ribosomal RNA data on the NJ tree. The 18S data were discussed for the first time for *Th. linarius, Th. angusticeps, Th. italicus, Th. meridionalis, Th. physapus, F. tenuicornis, Ch. kurdistanus, Te. anatolicus, Te. discolor, Ther. mohelensis* and *Ox. ajugae* species. Clearly results from the COI dataset in a single UPGMA tree separated the genera. The COI data of *Li. angulicornis, Te. anatolicus, Od. confusus, Od. dorycnii Th. angusticeps, Th. atratus, Th. italicus, Th. linarius* and *Th. meridionalis* were obtained for the first time by this study.

## 1. Introduction

Thysanoptera or thrips are characterized by having of a prolongable sac-like arolium at the top of each leg and by their asymmetric 'punch and suck' mouthparts in which the left side mandible only is developed (Heming, 1971; 1978). Scarcely 1 % of the described species thrips are potential pests (Mound and Teulon, 1995) but also, they have pollination, predation, and natural enemies opportunuties for agriculture (Mound, 2005). Thysanoptera is divided into two suborders; Terebrantia and Tubulifera and has approximately 6,337 extant species in 786 genera. Terebrantia is classified into seven families, Uzelothripidae, Merothripidae, Aeolothripidae, Adiheterothripidae, Fauriellidae, Heterothripidae and Thripidae. Thripidae with more than 2100 species, is the second largest family of Thysanoptera and most of the pest thrips, and all of the tospovirus vectors, belong to this family (Wiki, 2020). Although, the most known viral disease is *Tomato spotted wilt virus* (TSWV) but 26 different diseases caused by tospovirus by thrips transmission are recorded. (Rotenberg et al., 2015). Meanwhile the total number of thrips species recorded in Turkey from 193 (Tunç and Hastenpflug-Vesmanis, 2016) to 196 with three recent additions by Şahin et. al. (2019), Elekçioğlu (2020), Atakan and Pehlivan (2021), and out of these 116 species are from Thripidae. Though many species, that were reported as pests elsewhere, were also recorded in Turkey, however, among these, currently, only around 14 species are 'documented or potential pests' in this country as *Frankliniella intonsa* (Trybom), *Frankliniella occidentalis* (Pergande), *Thrips tabaci* Lindeman etc.

Polymorphism, lack of solid morphological characters in some cases, coexistence of different species in the same host plant, and high intraspecific variations, bring the need for taxonomic expertise (Murai and Toda,

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2001; Brunner et. al., 2004; Mound, 2012; Kadirvel et. al., 2013).

In addition, systematic status of the genera and species is changed by making the distinction later. On the other hand, early detection and correct and immediate identification of the pest species which stand in the quarantine list (Glover et. al., 2010; Smith-Pardo and O'Donnell, 2015) is very crucial. Furthermore, a simple, accurate, general, and easily applicable method is required in the integrated pest management (Rebijith et al., 2014). Molecular diagnosis seems a promising method to address the problems encountered in morphological diagnosis (Immaraju et. al., 1992; Brødsgaard, 1994; Zhao et. al., 1995; Karadjova, 1998; Kontsedalov et. al., 1998; Jensen, 2000; Espinosa et. al., 2002; Rugman-Jones et. al., 2010).

DNA barcode is considered to be the most effective molecular approach in distinguishing cryptic species, biotypes, haplotypes and host-geographic genetic differences in sex and polymorphism. Besides having such advantages over traditional (morphological) taxonomy, DNA barcode is also assumed to be fast and cost-effective in data collection and analysis stages (Shufran et. al., 2000; Brunner et. al., 2004; Asokan et. al., 2007; Borisenko et. al., 2009; Glover et. al., 2010; Strutzenberger et. al., 2011; Rebijith et. al., 2012; Zhang et. al., 2012; Rebijith et. al., 2013). Nevertheless, DNA barcoding approach is not designated as a competitor to traditional taxonomy in the future, but as the formal protocol for the identification of insects and other groups and as a powerful tool to aid in the discovery and identification of new species (Jinbo et. al., 2011; Leite, 2012).

The present study was carried out to assist this method, which has been used for many organisms in recent years, to what extend would be reliable to establish a barcode system for Turkish Thysanoptera fauna. Thripidae specimens collected in Konya, Karaman and Mersin (Turkey) between 2015 and 2017, were studied using conventional and molecular taxonomy (DNA barcoding method).

## 2. Materials and Methods

Specimens of Thripidae (Thysanoptera) species collected from Konya, Karaman and Mersin (2015-2017) were studied through molecular analyses as a part of preliminary attempts to establish a barcoding system for Thysanoptera in Turkey. The specimens were collected by shaking plants on a tray and were preserved temporarily in small vials containing a mixture of 60% ethanol+glacial acetic acid (9: 1), later were transferred to vials containing permanent preservation fluid, 70% ethanol, and stored at + 4°C. Specimens were mounted either in Canada Balsam or in Hoyer's medium for microscopical examination. The protocol given by Mound and Kibby (1998) was followed for mounting in Canada Balsam. Specimens were kept in a mixture of phenol+lactic acide (1:1, weight) overnight before mounted in Hoyer's medium. Identification of specimens was carried out by İrfan Tunç. A Motic BA310 high resolution digital camera was used for photomicrography. Terminology follows zur Strassen (2003). Slide-mounted specimens are deposited in the Department of Plant Protection, Faculty of Agriculture, Selçuk University, Konya, Turkey.

Following the pre-diagnosis step, the 'CTAB' protocol developed by Doyle and Doyle (1987)was applied individually to all specimens for DNA isolation. The COI deg F1/R1 primers were used for the mitochondrial Cytochrome Oxidase Subunit I (COI) gene region (~350 bp) (Timm et al., 2008). The 18S Ribosomal RNA primers (~650 bp) F (GGTGAA-ATTCTTGGAYCGCGCAAGAC) and R (CGCG-TGCRGCCCCRGACATCTAAG) were designed by examining available sequences from Thripidae taxa deposited at GenBank. PCR reaction was consisted of 0.15 mM dNTP, 2.5 mM MgCl2, 2.5 µL reaction buffer solution, 0.75 units of Taq DNA polymerase (all fermantes) and 0.2 mM each primer, 1 µL of DNA per sample in a final volume of 25 µL. The PCR cycling conditions consisted of an initial denaturing step at 94°C for 150 s, followed by 35 cycles of 94°C for 50 s, 53°C for 50 s, and 72°C for 70 s for the COI amplification. On the other hand, an initial denaturing step at 95°C for 120 s, followed by 35 cycles of 95°C for 90 s, 60°C for 75 s, and 72°C for 75 s was applied for 18S rDNA amplification. After amplification of both gene region, PCR products were sent to Macrogen Inc for sequencing in both directions.

A single sequence (using forward and reverse sequence information) was obtained from 23 species in 9 genera in the COI and the 18S ribosomal RNA gene regions. They were assembled and manually corrected their taxonomic distances using Mega X analysis program. Each gene region and each species were individually aligned within themselves. Before trees analyses, the overall mean distances correlated using Mega X analysis program, which is calculation model to mean all individual pairwise distance between taxa. Each gene was analysed using one of the distance-based UPGMA (Unweighted Pair Group Method with Arithmetic) and NJ (Neighbor Joining) analysis methods (respectively COI and the 18S ribosomal RNA gene regions). The trees were made using the Kimura 2-parameter model (Kimura, 1980), the ratio change between positions is modeled by the gamma distribution (Shape parameter = 1), the software MEGA (X version) to align sequences for all thrips specimens and build the trees of both gene region variants using p-distances using 1000 bootstrapping iterations as suggested by Kumar et al. (2018). *Haplothrips distinguendus* (Uzel) (suborder Tubulifera) and *Aeolothrips ericae* Bagnall (suborder Terebrantia) were used as outgroups for phylogenetic trees, respectively as suggested by Crespi et al. (1996) and Brunner et al. (2002).

## 3. Results and Discussion

Twenty-three species in 9-genera were detected namely, *Chirothrips kurdistanus* zur Strassen, *Chirothrips manicatus* Haliday, *Frankliniella intonsa* (Trybom), *Frankliniella occidentalis* (Pergande), *Frankliniella tenuicornis* (Uzel), *Limothrips angulicornis* Jablonowski, *Odontothrips confusus* Priesner, Odo*ntothrips dorycnii* Priesner, *Oxythrips ajugae* Uzel, *Taeniothrips inconsequens* (Uzel), *Tenothrips anatolicus* (Priesner), *Tenothrips discolor* (Karny), *Tenothrips frici* (Uzel), *Thermothrips mohelensis* Pelikan, *Thrips angusticeps* Uzel, *Thrips atratus* Haliday, *Thrips italicus* Bagnall, *Thrips linarius* Uzel, *Thrips major* Uzel, *Thrips meridionalis* (Priesner), *Thrips physapus* Linnaeus, *Thrips tabaci* Lindeman and *Thrips trehernei* Priesner (Figure 1) in the present study.

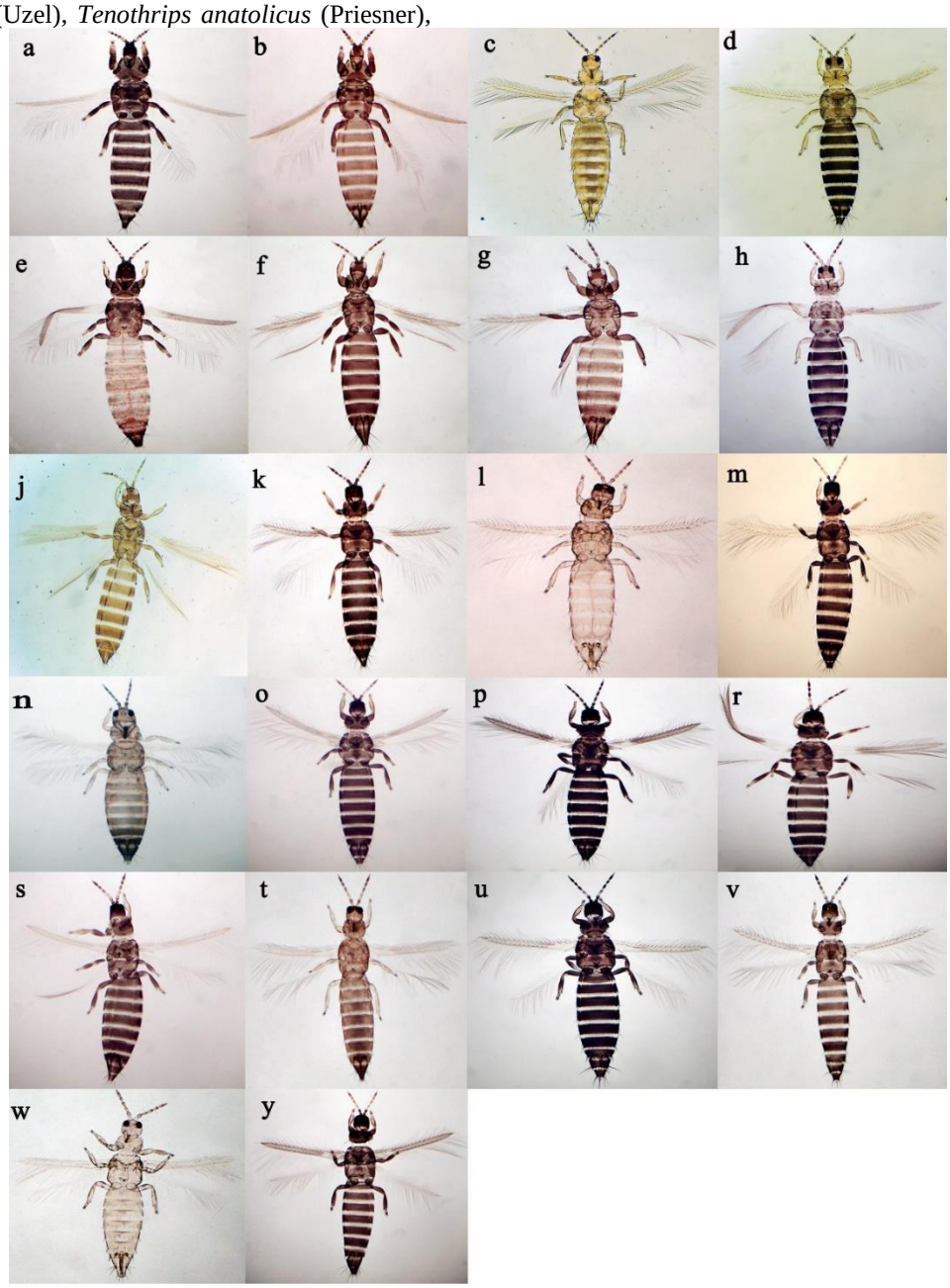


Figure 1
Slide photomicrographs of thrips species studied, all females a.*Chirothrips kurdistanus* b.*Chirothrips manicatus* c.*Frankliniella occidentalis* d.*Frankliniella intonsa* e.*Limothrips angulicornis* f.*Odontothrips confusus* g.*Odontothrips dorycnii* h.*Oxythrips ajugae* j.*Taeniothrips inconsequens* k.*Tenothrips anatolicus* l.*Tenothrips discolor* m.*Tenothrips frici* n.*Thermothrips mohelensis* o.*Thrips angusticeps* p.*Thrips atratus* r.*Thrips italicus* s.*Thrips linarius* t.*Thrips major* u.*Thrips meridionalis* v.*Thrips physapus* w.*Thrips tabaci* y.*Thrips trehernei.*

The phylogenetic positions of the 9-genera with two outgroups observed almost, with few exceptions, to form their own clades by the 18S Ribosomal RNA data on the NJ tree (Figure 2). *Chirothrips* sp., *Th. atratus* and *Te. frici* species were missing from the sequence library and therefore not represented in the tree. The 18S Ribosomal RNA overall mean distance among the species showed a value of 13% which means that mean 18S rDNA data divergence is 13% between the species.

Of the eight species in Thrips taxa appeared in same clade and these data were discussed for the first time for *Th. linarius*, *Th. angusticeps*, *Th. italicus*, *Th. meridionalis* and *Th. physapus* species. For three of the species in *Frankliniella*, there were good agreement from the reference specimens and the data was showed for the first time for *F. tenuicornis* species. However, the two species (*F. intonsa* and *F. occidentalis*) clades were not included the same reference specimens.

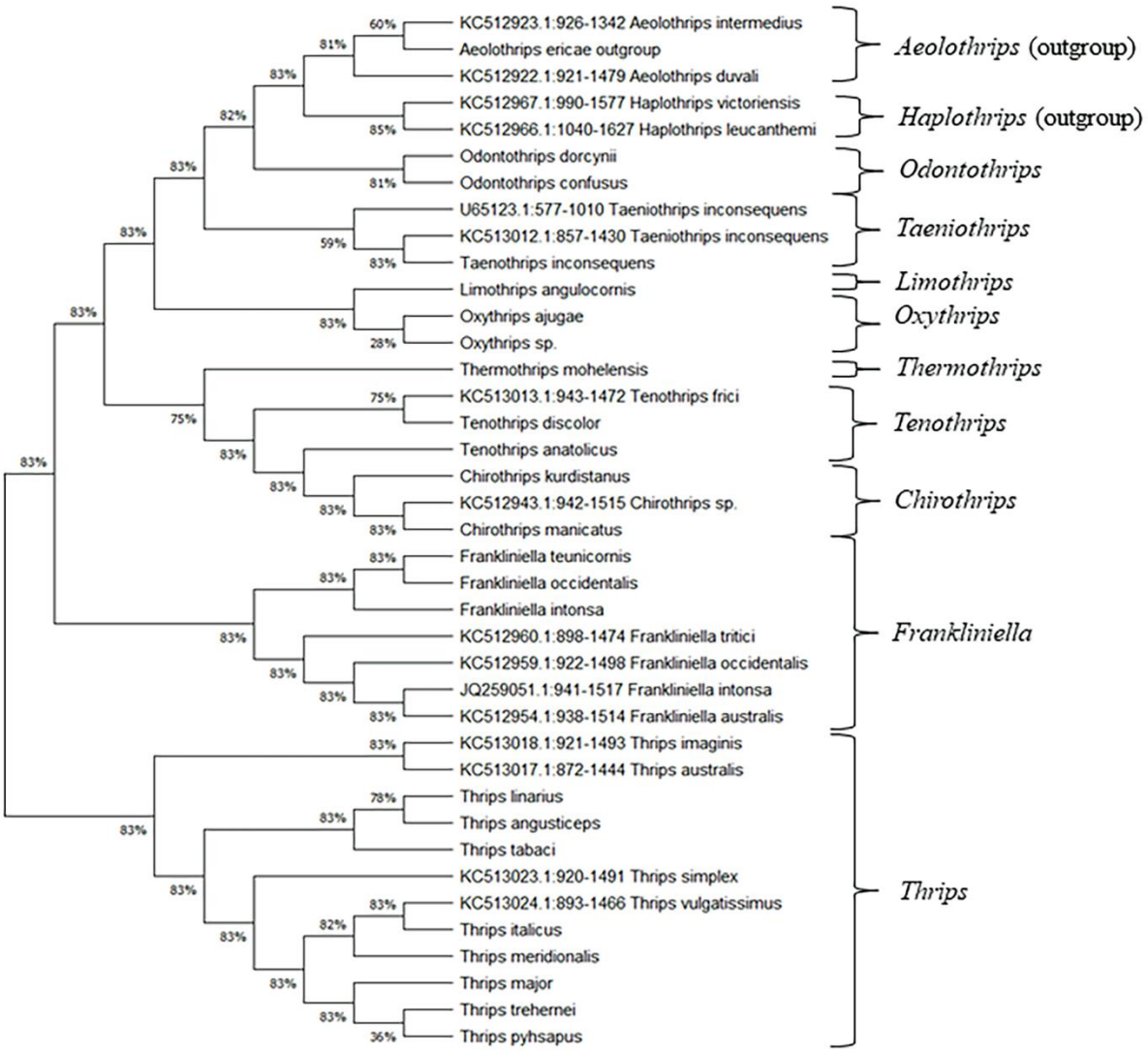


Figure 2
The NJ phylogenetic tree according to the 18S Ribosomal RNA gene region of Thripidae species studied with Mega X. *Aeolothrips ericae* Bagnall was used as outgroup. Sample sequences with numbers were taken from GenBank. (Overall mean distance: 0.13).

Of the two species in *Chirothrips*, recorded in one clade with the reference specimen (KC5122943.1 *Chirothrips* sp.), at the same time that was first time to represent for 18S Ribosomal RNA data of *Ch. kurdistanus*. By contrast *Te. anatolicus* species, which was in the first time for its 18S data, formed an unsupported clade, included *Chirothrips* species. In addition, *Tenothrips discolor* recorded in one clade with the reference specimen (KC513013.1 *Te. frici*) and in the first time for its 18S data in present study. *Thermothrips mohelensis*, the only species of the genus *Thermothrips* (zur Strassen, 2003), was detected for the first time in 18S Ribosomal RNA gene region. Its clade recorded with *Tenothrips*. And also, for first time in 18S rDNA data for *Oxythrips ajugae* and *Oxythrips* sp. species which were classified in a clade, but their clade included in one species *Limothrips*. Of the one species *Taeniothrips* clade recorded together with the two reference specimens. For the two species in *Odontothrips* recorded in one clade and for both are for the first time for 18S data.

18S Ribosomal RNA gene sequences have provided a well of information about phylogenetic relationships and have been used to make out phylogenetic past across a very wide aspect (Hillis and Dixon, 1991) and especially use to examine relationships among congeneric species and closely related genera (Hao et. al., 2013). Just as Hsieh et al. (2020) observed that their 16S mini-barcode system had resolution for species identification universality. Whereas Glover et. al. (2010) stated that when they aligned the ITS2, which is shorter and easier amplifying part of ITS (Hao et. al., 2013), there was unrelated thrips species sequence. Because, as they mentioned that if the ITS2 sequences of only a few species has aligned, it can be completely unrelated. Also, varied studies reported that ITS2 is not more variable than the other parts (van Herwerden et. al., 1999; Tkach et. al., 2000; Vilas et. al., 2005). However, our data came from 18S ribosomal gene region and Kuzoff et. al. (1998) stated that it has a ubiquity and conservative rate of evolution. Because of that the small-subunit ribosomal RNAs (18S) have proved useful for eukaryotes phylogenetic surveys, especially useful for inferring distant phylogenetic relationships between lack of any morphological characters (Sogin et. al., 1972; Woese, 1987; Field et. al., 1988; Turbeville et. al., 1991).

Clearly results from the COI dataset in a single UPGMA tree separated the 9-genera (Figure 3). *Frankliniella occidentalis*, *F. tenuicornis* and *Oxythrips* sp. species were missing from the sequence library and therefore not represented in the tree. The COI overall mean distance among the species showed a value of 24% which means that mean COI sequence divergence is 13% between the species. *Frankliniella intonsa* was observed within the references from NCBI in first clade shortly after the outgroup. There seemed that *Limothrips*, *Thermothrips* and *Oxythrips* species were represented within same clusters together. In addition, all *Oxythrips* were positioned in the same clade with the reference of (MK659499.1) *Anaphothrips* same as those 40 genera of *Anaphothrips* genus-group are recorded in world genera- which one is *Oxythrips*, *Anaphothrips* and *Thermothrips* by Masumoto and Okajima (2017) in their study. *Oxythrips ajugae* was formed with the reference of *Ox. ajugae* (FN546031.1) in the same clade.

The COI data of *Limothrips angulicornis* was obtained for the first time by this study and the species recorded in further clade than *Chirothrips* species cluster although *Chirothrips* and *Limothrips* have been placed together in a group called the Chirothripini (Mound, 2011). Moreover, they are quite different, for instance *Limothrips* has one pair of long postero-angular pronotum setae, when *Chirothrips* has two; the *Limothrips* maxillary palps segmented two, while *Chirothrips*'s three etc. (zur Strassen, 2003), but both of them called grass-living thrips by Mound (2011). One of our unknow species *Chirothrips* sp. was located between reference MF748558.1 *Ch. manicatus* and our sample in the tree. This case suggests it could possibly be in the *Chirothrips manicatus* species-group as reported by Minaei and Mound (2010).

For three of the species in *Tenothrips*, there were good agreement from the reference specimens for *Tenothrips frici* and *Te. discolor*. *Tenothrips anatolicus* data was obtained for the first time for COI gene region and the species was represented another cluster but shortly after with the two *Tenothrips* species. Of the one species in *Taeniothrips* appeared in same clade with the reference specimens. Bhatti (1967) submitted *Tenothrips* as a subgenus of *Taeniothrips* by referring to its trapezoidal pronotum and the basisternum flange of its prothorax with distinct anterolateral lobes. Morphologically, *Tenothrips* and *Taeniothrips* are almost identical in their 8-segmented antennae, Tergite VIII without ctenidium and brown color. However, *Tenothrips* always has two pairs of ante-ocellular setae on the head while *Taeniothrips* species has only one pair (zur Strassen, 2003). And also, as mentioned by Mound (1981) *Taeniothrips* genus-group has not included *Tenothrips* because of some morphological characters. Secondly Bhatti (2003) suggested that *Tenothrips* shares many characters and there are no obvious morphological differences with *Ceratothrips*, a genus of the *Megalurothrips* genus-group. Therefore, diagnosis of it and related genera needs extensive study according to Zhang et. al. (2019). Despite all these studies and different characters, between *Tenothrips* and *Taeniothrips* relationship was talked in the title of *Taeniothrips* genus-group study (Wang et al., 2020).

A total of two of *Odontothrips* species recorded in one cluster with the reference specimens and for the first time for COI data in the literature. Moreover, there is no very big differences between their morphology and also no big molecular difference was observed, only one base in their COI data (data not shown). When we looked at their morphological characters, *Od. confusus* is just larger species than *Od. dorycnii* for example, in terms of the setae $S_1$ on tergite IX (respectively >140 µm and 90 µm), the hind tibia (respectively 210 µm and 178 µm), body length (respectively 1720-2060 µm and 1430-1650 µm) etc. (zur Strassen, 2003).

The Thrips representing nine species (and five NCBI references) formed distinct 3 clades in a different place from *Frankliniella* genus and also their genus-groups, are not closely related (Mound, 2002). Similarly, Karimi et. al. (2010) indicated that *Thrips* species formed different cluster but stood close together themselves in the phylogenetic tree. The COI data of *Th. angusticeps*, *Th. atratus*, *Th. italicus*, *Th. linarius*, and *Th. meridionalis* were recorded for the first time in present study. *Thrips meridionalis* recorded in a clade with the reference of *Th. vulgatissimus* same as Mound and Masumoto (2005) pointed out the close morphological similarity of them. For instance, there is only little difference about their color of antennal segment III, their length of antennal segments VII and VIII (zur Strassen, 2003). And also, another morphological similarity Thrips including *Th. trehernei* to *Th. physapus*, which was indicated the similarity by Mound and Masumoto (2005), located in a same clade. Both *Thrips* species has only a few morphological characters; *Th. trehernei* abdominal segment X mostly longer than 80 µm (75-95 µm) and its dorsal longitudinal split taking up only 70-85% of the segment length, while *Th. physapus* abdominal segment X mostly shorter than 80 µm (58-82 µm) and it's split occupying 86-95% of segment length. *Thrips major* and *Th. tabaci* formed in the same clade with their reference specimens. The *Chirothrips* representing three species formed innermost one clusters but distinct 3 clades in the tree.

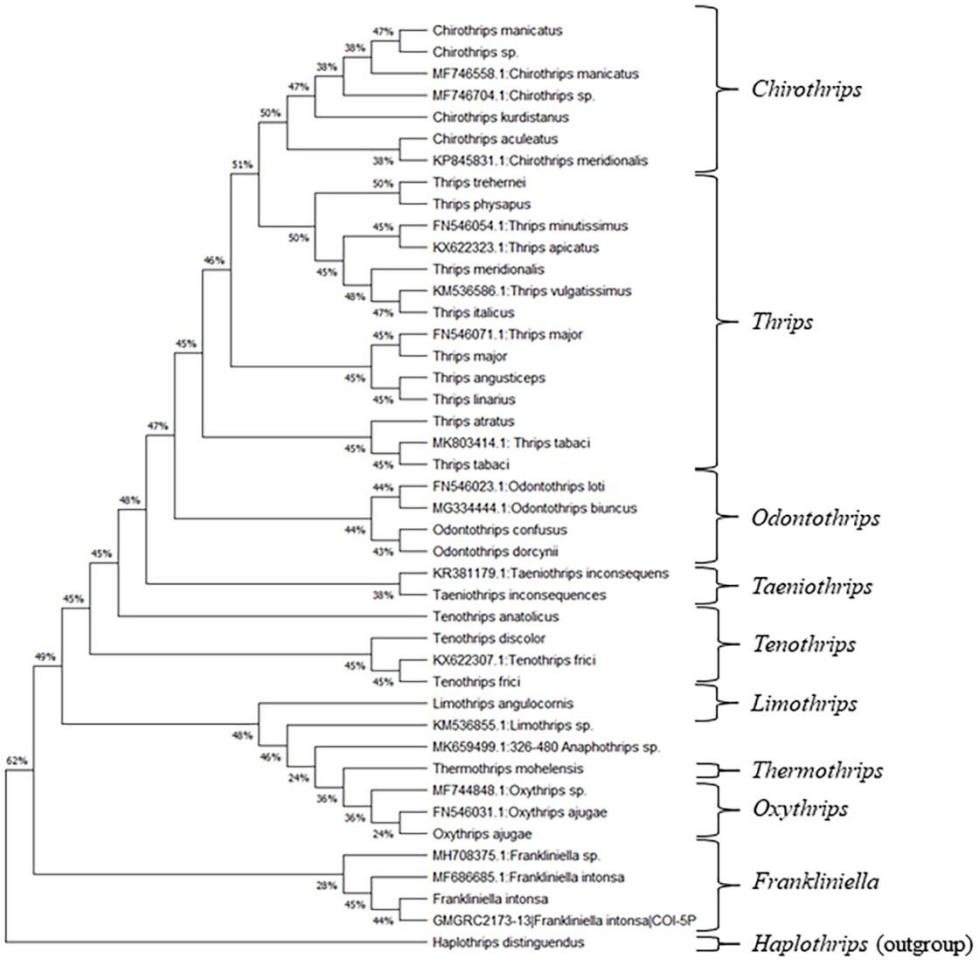


Figure 3
The UPGMA phylogenetic tree according to the COI gene region of Thripidae species studied with Mega X. *Haplothrips distinguendus* was used as outgroup. Sample sequences with numbers were taken from GenBank. (Overall mean distance: 0.24).

One of the best-known barcoding gen regions is COI to subserve as the core of a global bio identification system for insects (Hebert et. al., 2003b). The COI-based identification system provides the small number sampling of higher taxonomic categories and species-level assignments (Hebert et. al., 2003a). Secondly, the other cytochrome oxidase dataset as COIII also demonstrated acceptable loci for the diagnoses of the low-density of thrips according to Glover et. al. (2010). The dataset consisted of COI sequences supported the selected species morphological identification. Similarly, Fiala et. al. (2015) and Taddei et. al. (2021) stated that their thrips

COI sequences confirmed the species identifications based on morphological characters too. Our results agree with Kadirvel et. al. (2013a) reported the partial COI identification method successfully performed for at least 86% for the four major thrips species (*Thrips palmi* Karny, *Th. tabaci*, *Scirtothrips dorsalis* Hood and *F. occidentalis*). Marullo et. al. (2020) suggested that the COI barcoding system is useful to identify and classify thrips multiple species occurring in a crop system even though there were some misidentifications in their COI results, as they mentioned cause their technical problems such as ineffective primer selection.

The classical taxonomy has its own power, but DNA barcoding employing COI or 18S Ribosomal RNA has the added advantage for the target species to set up the suitable pest management strategies and quarantine processes (Rebijith et. al., 2013; Chakraborty et. al., 2019). A major current focus in integrated taxonomy is how to combine with morphology and molecular data successfully evidenced to identify the thrips species (Iftikhar et. al., 2016; Tyagi et. al., 2017). In this paper, the collected species of the 9-genera thrips from Turkey successfully identified via both classical and molecular taxonomy by both regions. Also, as Chakraborty et. al. (2019) we think that there has to be thorough taxonomic studies for more thrips species to diagnose with multiple molecular markers in the thrips systematics research. However, a complete and well-support reference library is an essential for molecular identification (Meyer and Paulay, 2005; Collins and Cruickshank, 2013). Apart from that, one of the key powers of the DNA barcoding method is the normalization of the locus used (Glover et. al., 2010).

The phylogenetic trees produced in the present study are assumed to be only a small step, and much work is needed at the species level. It has been realized that sampling in wider geographical areas aiming to collect the highest number of samples, possible, is required in Turkey in order to obtain barcoding data that would satisfactorily address the problems faced in conventional systematics of Thysanoptera.

The sequences obtained by Sanger sequencing from the COI and 18S Ribosomal RNA gene regions of the species studied were evaluated on the phylogenetic tree by UPGMA and NJ analysis. Considering the results of DNA barcode analysis with both markers, it may be assumed that the species-level distinction was possible for the COI gene region while the 18S Ribosomal RNA gene region did not yield the data required to discriminate satisfactorily at the species level.

Extensive mitochondrial sequencing information of all thrips species should be shared and included in phylogenetic studies since the phylogenetic trees made with DNA sequences have the potential to be misinterpreted Brunner et. al. (2002).

It can be concluded that these and similar studies, in which morphological and molecular diagnosis are made together. It is obvious that the rapid sequencing of a part of mitochondrial gene region by advanced molecular diagnostic studies will benefit science and agriculture. The use of COI gene regions, rather than the use of 18S Ribosomal RNA gene region seems more favorable for barcoding studies. The COI gene region, which gives the best diagnostic separation in the molecular method, should be completely extracted for all species, and should be enriched in the free and easy-to-access databases such as BOLD or GenBank.

## 4. Acknowledgements

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**Research Article**

# Assessment of Processing Quality Traits of Different Potato Genotypes in Konya

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**ABSTRACT**

This study aimed to determine the potato breeding lines that show superior processing quality traits and can be candidate variety by selection. The study was conducted according to The Randomized Plots Trial Design with four replications in 2019 and 2020. In the study, 26 potato breeding lines developed by Selcuk University, Faculty of Agriculture, Department of Field Crops, and 4 registered varieties as plant material were used in the two years. The varieties and lines were harvested in the fields and then the genotypes were evaluated according to processing quality traits. In the study; dry matter ratio (%), chips yield (%), French fries yield (%), chips, and French fries color (L*, b*) parameters were examined. Dry matter ratio, chips yield and French fries yield, and chips and French fries color values were found important statistically in terms of years, genotypes, year x genotype interactions. Values of chips and French fries color were varied from only genotypes averages. According to two years average, results showed large variations for examined parameters; dry matter ratio changed between 16.8-20.9 %, chips yield was 34.1-51.0 %, French fries yield was 30.7-44.9 %, chips color values (L*, b*) were 19.4-67.1, 8-44 and French fries color values (L*, b*) were 11.4-71.5, 13.5-58.2, respectively.

## 1. Introduction

Potatoes are mainly perennial plants in temperate climates. However, the potato plant adapted to the annual development period in the places where its culture was carried out and physiologically acquired an annual feature. Currently, it is located at an altitude of 4000 meters above sea level. It is spread over a very large area from the 70th North latitude to the 50th Southern latitude and has a close adaptation to cereals. *Tuberosum* groups decrease to sea level as they approach the adaptation limits, and rise to an altitude of 1500-2000 meters as they approach the Equator, as in the Andes since it can form tubers at certain degrees. Although it is spread over a very wide area, it also presents many differences in cultivation technique and post-harvest processes (Sencar et al., 1994; Caliskan, 2001).

Potatoes, which are cultivated worldwide and included in the family of *Solanaceae*, are botanically classified as *Solanum tuberosum* subsp *tuberosum.* There are 95 species belonging to the *Solanaceae family*. In addition to the potato plant; *Solanum* species, which include tomatoes, peppers, eggplants, tobacco, and some ornamental plants, economically represent the most important and largest group. There are about 2000 types of these species, and about 150 are tuberous species. These include polyploid series from diploid (2x) to hexaploid (6x) (75 % of them are diploid) (Sleper and Poehlman, 2006; Bradeen et al., 2011).

A potato tuber contains approximately 13-37 % dry matter, 13-30 % carbohydrates, 0.7-4.6 % protein, 0.02-0.96 % lipids, and about 0.44 % ash (Salunkhe et al., 1991). In addition, it also contains important dietary sources such as; potassium, fiber, vitamins C and B6, essential amino acid, and other elements. For example, in a large potato tuber (≅ 299 g) There are 278 calories (1164 kJ). It contains vitamins E as well as minerals K, Mg, Ca, Mn, P, Na, and Fe in low amounts (Bradeen et al., 2011; Anonymous, 2021a).

It is possible to divide the consumption market into two cooking and industrial. There are certain criteria regarding which potato variety can be considered an industrial potato. These can be listed as factors such as the specific gravity of the tuber, dry matter ratio, the amount of reduced sugar, the starch ratio (only for starch type varieties), and the color and external characteristics of the tuber. Potatoes contain 15-25 % of dry matter. For industrial-type potatoes, the dry matter ratio should be 20 % and higher, the starch ratio should be 13 % and higher, and the specific gravity should be 1.080 and higher (Kirkman, 2007; Gunel et al., 2010; Haque et al., 2018).

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In recent years, the development of potato varieties in our country has gained momentum. As a result, today there are 191 registered varieties of potatoes. Some of our national varieties were improved by; Ege University Faculty of Agriculture (Nif), Doga Tohumculuk (Kutup, Zirve, Doruk, İlkmor, Bahar, Kaya, Volkan, Yaprak, Yediveren, Yaldız, Maden, Ayaz, Yankı), Gazi-osmanpasa University Faculty of Agriculture (Basciftlik Beyazi), Nigde Potato Research Institute Directorate (Fatih, Nahita, Nam, Unlenen, Onaran 2015, Cagli, Muratbey, Leventbey, Saruhan, Nigsah), İnan Meijer Seed Growing (Sultan Ecem, Sultan Nur), Yuksel Seed Growing (Asya, Soylu, Cevher, Demet, Maraton) and brought in our country (Anonymous, 2021b).

It is necessary to free the tuber seed cultivation from being dependent on imports and support the high-level (Super Elite, Pre-Elite, etc.) seed cultivation system in order to domestic potato production to reach the desired level. Although there is still no incentive system in force in this regard, some companies have turned to the production of starting materials with tissue culture in recent years. It takes 5-6 years for the seeds to reach the producer with this process, it is necessary to implement a special incentive system for this process (Caliskan et al., 2020).

This study aimed to evaluate certain quality parameters of some trade registered potato varieties and lines developed by Associate Professor Rahim Ada show superior processing quality traits and can be candidate variety by selection. It is important to collect and define data on quality parameters in order to develop varieties with superior characteristics in breeding studies. It is necessary to reveal the characteristics of the potato lines in the selection process of breeding programs for the development of domestic potato varieties.

## 2. Materials and Methods

The breeding lines were selected as crossbreed seeds that were developed to 5th field generation by selection. The information about these lines and varieties are shown in the Table 1.

The study was conducted according to "Randomized Complete Blocks Design" with four replications between 2019 and 2020. The field studies were conducted at Selcuk University Faculty of Agriculture Abdulkadir Akcin Trial Field in Konya. In 2019, planting was done manually in the plant beds that were determined by markers as 70 cm x 30 cm (row spacing – intra-row) on 30th April 2019. In 2020, experiment were done by potato planting machine on 20th April 2020. The each parcel was organized as 3 meters long by making 2 rows for each genotype in the experiment. All genotypes were produced and harvested in Konya during the 2019-2020 vegetation periods.

Table 1
Information on potato varieties and breeding lines used in the study

| GENOTYPES | USAGE |
|---|---|
| AFAGR6 | Chips |
| AFAGR7 | Chips |
| AFAGR9 | Chips |
| AFAGRB | Chips |
| AFXBRO3 | Combine Type* |
| AFHER3 | Cooking |
| AFLA5 | French Fry |
| AFLA11 | French Fry |
| ELAF6 | Cooking |
| ELAF7 | Cooking |
| GRANAFA | Cooking |
| HERAF6 | Chips |
| LOLA1 | French Fry |
| POMAFA | French Fry |
| POMT2/5 | French Fry |
| T1AGR1 | Cooking |
| T1AGR13 | Cooking |
| T3AG2 | Cooking |
| T3AG4 | Cooking |
| T3LA3 | Combine Type |
| T3LA7 | Combine Type |
| T3LA10 | Combine Type |
| T3POM2 | Combine Type |
| T3POM6 | Combine Type |
| T3POM9 | Combine Type |
| T7POM1 | Combine Type |
| DİDO | Cooking |
| HERMES | Chips -Industry |
| RUMBA | Cooking |
| VAN GOGH | French Fry |

*Cooking-Chips-French Fry

According to Caliskan (2001), the dry matter ratio in the tuber samples taken from each parcel after harvesting, the productivities of chips and French fry according to the method indicated by Senol (1973), and frying color scales with using the Minolta Chroma Meter (Minolta Corp., Ramsey, NJ). have determined.

In the study; dry matter ratio (%), chips yield (%), French fries yield (%), chips, and French fries color (L*, b*) parameters were examined.

The data were analyzed using the technique of analysis of variance (JUMP) and treatment means were separated by Least Significant Differences (LSD) a 1 % probability level by using MSTAT-C as described by Nissen (1989).

## 3. Results and Discussion

The variance sources and their statistical significance are shown in Table 2 for the dry matter ratio (%), chips yield (%), French fries yield (%), chips, and French fries color (L*, b*) parameters.

Table 2
Results of variance analysis of some quality parameters of 30 potato genotypes in the experiment

| Source of Variation | Means square | | | | |
|---|---|---|---|---|---|
| | df | Dry matter ratio (%) | Chips yield (%) | French fries yield (%) | |
| Years | 1 | 1,05** | 539,40** | 13,21** | |
| Replication [Y] | 29 | 9,30 | 186,97 | 138,61 | |
| Genotypes | 6 | 0,07** | 7,44** | 1,90** | |
| Y x G | 29 | 1,22** | 78,95** | 61,63** | |
| Error | 174 | 0,17 | 3,52 | 2,85 | |
| Source of Variation | df | Chips L value | Chips b* value | French fries L* value | French fries L value |
| Years | 1 | 51,52 | 14,46 | 134,70 | 9,36 |
| Replication [Y] | 29 | 1042,85 | 522,30 | 1409,32 | 781,66 |
| Genotypes | 6 | 135,28** | 26,86** | 25,20** | 40,05** |
| Y x G | 29 | 87,51 | 60,06 | 94,19 | 80,08 |
| Error | 174 | 119,88 | 100,43 | 69,37 | 83,89 |

*P < 0.05, **P < 0.01

The dry matter content is closely related to the starch content. In addition to the genetic structure of the tubers, the ecological conditions in which they are grown and the cultural practices in the field affect the dry matter and its distribution. On the contrary, there is a higher dry matter ratio in late maturation tubers and tubers grown at high altitudes. Most importantly, the difference in the tubers quality directly affects the dry matters proportion (Yilmaz and Karan, 2011). In addition, the content of dry matter in the tuber varies depending on certain areas of the tuber. While there is a smaller amount of dry matter in the center of the tuber, the more dry matter ratio is determined towards the ends of the tuber. In this case, the dry matter ratio is the highest in the stolon parts, and this dry matter change on the tuber fluctuates by the 7 % (Gaze et al., 1998; Pringle et al., 2009).

The values procured in terms of the dry matter ratio, which is one of the most important quality criteria of potato tubers, displayed significant differences (P <0.01) according to years and genotypes (Table 2). The average dry matter ratios of the genotypes varied between 16.7 % and 20.9 %. The highest dry matter content was recorded in the T3LA7 line with 20.9 %, and the lowest ratio was detected in the T1AGR1 line with 16.7 %. Differences in dry matter ratios of genotypes were found over the years (Table 3).

Dry matters of industrial genotypes turned out to be higher than edible types. Thus, the desired dry matter range for industrial potatoes is higher than 20 %, and the desired reduced sugar content range is lower than 0.1 % (Marwaha et al., 2010).

Our findings indicate that the dry matter ratio is influenced by environmental factors as well as genetic structure, and generally industrial varieties have a higher dry matter ratio. This statement showed similarities with the findings of Sanli and Karadogan (2012), Karan (2013), Arioglu et al. (2018), and Bulbul (2018) Naeem and Caliskan (2020).

High dry matter content, less oil absorption of chips, crispy consistency in the mouth, lower reduced sugar and light frying color are bunch of the defining quality criteria in industrial potatoes (de Freitas et al., 2006). There is also a relationship between the dry matter content and the frying efficiency and frying color. The high dry matter content increases the productivity of chips, provides a crispy consistency in the mouth and less oil absorption during frying process(Pedreschi et al., 2005; Rommens et al., 2010). In our study, both the chips and finger potatoes productivities were found to be high in varieties with high dry matter ratios. Hence, high dry matter ratios as well as high frying efficiency were detected in lines such as T3LA7, T3POM2, T3POM6, T3POM9, AFLA5, LOLA1, T3LA10 (Table 3).

The main criteria for the chips and French fry sector can be listed as follows; After frying, there should be not problems in sugar content, mouthfeel, aftertaste, crispness, inner color and texture, it should be easily peeled and resistant to storage (Guenthner, 2020). In addition, the content of dry matter is one of the most important factors affecting the texture of potatoes. The frying efficiency of chips and finger potatoes is mainly related to their dry matter content (O'Donoghue et al., 1996).

Potato varieties are classified according to the quality characteristics of the tuber like special cooking and processing properties, such as boiled, French fry. It is decided whether a variety is a potato chip or a finger potato by considering its many properties. The tuber appearance of French fry is long and thin, this the length can be up to 10 cm. For potato chips, the type of tuber should be round (Jansen et al., 2001; Anonymous, 2021c).

Potatoes with a high starch content are preferred because they absorb less fat during frying (Stark, 2003). The oil content and texture of potato chips are also influenced by the frying temperature and the type of oil used for frying (Kita et al., 2007).

Table 3
Means of Dry matter ratio (%), chips yield (%), French fries yield (%) of 30 potato genotypes evaluated under Konya location in 2019-2020 years.

| Genotypes | Dry matter ratio (%) | | | Chips yield (%) | | | French fries yield (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2020 | Mean | 2019 | 2020 | Mean | 2019 | 2020 | Mean |
| AFAGR 6 | 20,4 a-d | 19,5 p-h | 19,9 d-h | 46,3 h-n | 31,4 z | 38,9 j-l | 46,6 c-f | 42,4 ı-p | 44,5 c-g |
| AFAGR7 | 19,3 g-ı | 18,9 h-l | 19,1 ı-l | 38,4 u-w | 37,7 u-x | 38,1 kl | 38,9 q-v | 36,0 v-y | 37,5 mn |
| AFAGR9 | 20,3 b-e | 18,4 j-l | 19,3ı-k | 45,1 ı-q | 46,2 h-n | 45,7 d-g | 47,1 c-e | 38,1 s-w | 42,6 g-j |
| AFAGRB | 21,0 ab | 19,6 e-h | 20,3 b-e | 54,9 ab | 47,0 f-l | 51,0 a | 51,0 a | 42,2 j-p | 46,6 bc |
| AFXBRO3 | 18,4 j-l | 18,9 h-l | 18,6 l-m | 38,1 u-w | 46,3 h-m | 42,2 hı | 41,5 m-r | 34,6 x-z | 38,1 m |
| AFHER3 | 17,5 mn | 19,3 g-ı | 18,4 n | 46,1 h-o | 34,5 x-z | 40,3 ı-k | 46,3 c-g | 31,8 z | 39,1 k-m |
| AFLA5 | 20,5 a-c | 20,3 b-e | 20,4 a-d | 46,9 g-m | 54,5 ab | 50,7 a | 40,9 o-t | 46,3 c-g | 43,6 e-ı |
| AFLA11 | 19,0 g-k | 19,1 g-j | 19,0 k-m | 48,7 d-h | 50,4 c-f | 49,5 ab | 44,7 c-l | 44,2 e-n | 44,5 c-g |
| ELAF6 | 19,5 f-h | 19,6 e-h | 19,5 g-k | 45,7 h-p | 53,7 a-c | 49,7 ab | 44,2 e-n | 45,5 c-ı | 44,9 c-f |
| ELGAF7 | 20,3 b-e | 19,4 f-ı | 19,8 e-ı | 40,5 s-u | 51,6 b-d | 46,0 d-f | 44,4 d-m | 50,7 ab | 47,5 ab |
| GRANAFA | 19,6 e-h | 17,4 no | 18,5 mn | 47,6 e-k | 46,3 h-n | 47,0 c-e | 45,3 c-j | 46,4 c-g | 45,9 b-d |
| HERAF6 | 18,3 kl | 18,3 kl | 18,3 n | 44,3 k-r | 54,6 ab | 49,4 a-c | 47,6 bc | 51,2 a | 49,4 a |
| LOLA1 | 20,8 a-c | 20,4 a-d | 20,6 ab | 47,9 e-j | 53,2 a-c | 50,5 a | 42,0 k-q | 45,5 c-ı | 43,7 e-ı |
| POMAFA | 17,4 no | 17,3 no | 17,4 o | 44,0 l-v | 43,1 n-s | 43,5 gh | 47,5 cd | 38,4 r-v | 43,0 f-j |
| POMT2/5 | 18,9 h-l | 19,4 f-ı | 19,1 j-l | 35,2 w-y | 46,4 h-v | 40,8 ıj | 40,5 o-u | 44,9 c-k | 42,7 g-j |
| T1AGR1 | 16,2 p | 17,1 no | 16,7 p | 37,9 u-x | 42,5 p-s | 40,2 ı-k | 40,7 o-t | 41,2 n-s | 41,0 j-l |
| T1AGR13 | 19,4 f-ı | 19,0 g-k | 19,2 t-k | 44,5 j-r | 43,5 n-s | 44,0 f-h | 33,6 b-z | 38,0 t-w | 35,8 n |
| T3AG2 | 18,4 j-l | 18,4 j-l | 18,4 n | 35,0 w-y | 43,4 n-s | 39,2 j-l | 27,3 z | 37,5 u-x | 32,4 o |
| T3AG4 | 18,5 j-l | 18,7 ı-l | 18,6 l-n | 35,9 v-y | 38,9 t-u | 37,4 l | 30,8 z | 30,5 z | 30,7 o |
| T3LA3 | 18,2 lm | 18,3 kl | 18,3 n | 42,2 q-t | 45,3 h-q | 43,7 f-h | 42,0 k-q | 41,2 n-s | 41,6 ı-j |
| T3LA7 | 21,1 a | 20,6 a-c | 20,9 a | 44,9 ı-q | 50,3 c-g | 47,6 b-d | 41,3 mr | 43,6 f-o | 42,4 g-j |
| T3LA10 | 20,3 b-e | 20,5 a-c | 20,4 a-d | 45,0 ı-q | 55,9 a | 50,4 a | 41,5 m-r | 45,3 c-j | 43,4 f-ı |
| T3POM2 | 19,4 f-ı | 19,4 f-ı | 19,4 h-k | 35,5 v-y | 42,7 o-s | 39,1 j-l | 35,2 w-y | 42,7 h-p | 38,9 lm |
| T3POM6 | 20,1 c-f | 20,1 c-f | 20,1 b-f | 41,9 q-t | 46,1 h-o | 44,0 f-h | 46,1 c-g | 46,4 c-g | 46,2 b-d |
| T3POM9 | 19,7 d-g | 20,3 b-e | 20,0 c-g | 45,1 ı-q | 50,5 c-e | 47,8 b-d | 42,6 h-p | 41,7 l-q | 42,1 h-j |
| T7POM1 | 17,0 no | 16,7 op | 16,8 p | 35,0 w-y | 33,2 yz | 34,1 m | 44,1 e-n | 41,5 m-r | 42,8 f-j |
| DİDO | 18,4 j-l | 18,5 j-l | 18,4 n | 36,2 b-y | 41,1 r-u | 38,6 j-l | 43,5 f-p | 44,8 c-l | 44,2 d-h |
| HERMES | 19,3 g-ı | 19,6 e-h | 19,4 h-k | 48,2 d-ı | 53,0 a-c | 50,6 a | 45,7 c-h | 45,5 c-ı | 45,6 b-e |
| RUMBA | 20,5 a-c | 20,5 a-c | 20,5 a-c | 43,1 n-s | 47,0 f-l | 45,0 e-g | 44,3 e-n | 37,9 ı-n | 41,1 j-k |
| VAN GOGH | 19,7 d-g | 19,6 e-h | 19,6 f-j | 45,9 h-p | 45,9 h-p | 45,9 d-g | 43,3 g-p | 40,4 p-u | 41,8 ıj |
| Mean | 19,2 a | 19,1 b | 19,2 | 42,9 b | 45,9 a | 44,4 | 42,3 a | 41,9 b | 42,1 |
| | $Lsd_{genotype\ (0.01)}$ = 0,5 | | | $Lsd_{genotype\ (0.01)}$ = 2,4 | | | $Lsd_{genotype\ (0.01)}$ = 2,2 | | |
| | $Lsd_{year\ x\ genotype\ (0.01)}$ = 0,8 | | | $Lsd_{year\ x\ genotype\ (0.01)}$ = 3,5 | | | $Lsd_{year\ x\ genotype\ (0.01)}$ = 3,1 | | |

The significant (P <0.01) differences were determined among the chips productivities of the potato genotypes used in the study according to the years and genotypes (Table 2). Frying productivities were determined above 50 % in lines of AFLA5 50,7 ( %), LOLA1 (50,5 %), T3LA10 (50,4 %), and varieties of Hermes (50,6 %) in the same statistical group. It is expected that the productivities of chips will also vary depending on the alteration in the dry matter ratios of the genotypes over the years (Table 3). The quality of chips is affected by the size of the tuber, its shape, eye depth, specific gravity, dry matter and reduced sugar levels. These factors depend on cultural practices, environmental conditions, and genotype. However, the genetic component has the strongest effect, since the properties are inherited. In a study conducted by

(Abong et al., 2012). Karadogan (1994a), it was reported that there was a positive relationship among the potato chips; they stated a negative relationship among the protein ratios and oil absorption ratios. As a matter of fact, frying efficiency of these genotypes with high dry matter ratio was also found to be high (Table 2). This is due to the fact that the water loss during frying is less in tubers with a high dry matter ratio (Sanli and Karadogan, 2012).

The significant (P <0.01) differences were determined between the French fry productivities of the potato genotypes used in the study compared to the years and genotypes (Table 2). French fry productivity is related to the dry matter ratio, and it productivities of genotypes with a high dry matter ratio are also high (Karadogan, 1994a). Also in this study, French fry productivities of genotypes with a high dry matter content were high (HERAF6 ‘ 49.4%’, dry matter average ‘18.3%’; ELAF7 ‘ 47.5%’, dry matter average ‘19.8%’) (Table 3).

Table 4
Means of some quality parameters of 30 potato genotypes evaluated under Konya location in 2019-2020 years.

| Genotypes | Chips L* value | | | Chips b* value | | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | Mean | 2019 | 2020 | Mean |
| AFAGR 6 | 39,2 | 38,0 | 38,6 e-h | 9,4 | 20,3 | 14,9 ı-k |
| AFAGR7 | 29,6 | 31,9 | 30,7 g-ı | 36,3 | 33,6 | 34,9 a-d |
| AFAGR9 | 36,3 | 37,7 | 37,0 e-h | 27,4 | 26,7 | 27,0 b-ı |
| AFAGRB | 46,9 | 46,1 | 46,5 b-f | 17,6 | 19,4 | 18,5 e-k |
| AFXBRO3 | 58,4 | 59,4 | 58,9 ab | 8,6 | 7,4 | 8,0 k |
| AFHER3 | 60,3 | 68,5 | 64,4 a | 13,3 | 13,1 | 13,2 jk |
| AFLA5 | 40,4 | 36,1 | 38,3 e-h | 24,1 | 27,7 | 25,9 c-j |
| AFLA11 | 16,8 | 22,1 | 19,4 ı | 44,0 | 45,6 | 44,8 a |
| ELAF6 | 41,0 | 39,4 | 40,2 e-h | 24,6 | 31,5 | 28,1 b-g |
| ELGAF7 | 50,7 | 66,9 | 58,8 a-c | 31,6 | 28,5 | 30,0 b-f |
| GRANAFA | 33,4 | 29,3 | 31,3 g-ı | 37,2 | 38,3 | 37,8 a-c |
| HERAF6 | 42,2 | 46,7 | 44,5 d-g | 21,9 | 17,2 | 19,5 e-k |
| LOLA1 | 69,4 | 64,8 | 67,1 a | 26,2 | 25,6 | 25,9 c-j |
| POMAFA | 44,8 | 39,8 | 42,3 e-g | 14,9 | 20,2 | 17,6 f-k |
| POMT2/5 | 37,5 | 40,5 | 39,0 e-h | 18,8 | 14,1 | 16,4 g-k |
| T1AGR1 | 38,9 | 36,1 | 37,5 e-h | 31,2 | 21,6 | 26,4 c-ı |
| T1AGR13 | 43,2 | 46,0 | 44,6 c-g | 16,5 | 13,6 | 15,0 h-k |
| T3AG2 | 30,7 | 30,6 | 30,6 g-ı | 26,2 | 26,6 | 26,4 c-ı |
| T3AG4 | 44,3 | 43,1 | 43,7 d-g | 26,3 | 20,6 | 23,5 d-j |
| T3LA3 | 66,7 | 48,8 | 57,7 a-d | 26,7 | 30,7 | 28,7 b-g |
| T3LA7 | 62,7 | 58,4 | 60,5 ab | 22,9 | 34,1 | 28,5 b-g |
| T3LA10 | 39,4 | 40,0 | 39,7 e-h | 23,6 | 22,6 | 23,1 d-j |
| T3POM2 | 39,5 | 39,0 | 39,2 e-h | 25,6 | 27,7 | 26,6 c-j |
| T3POM6 | 41,8 | 55,2 | 48,5 b-e | 26,2 | 22,1 | 24,2 d-j |
| T3POM9 | 31,9 | 34,5 | 33,2 f-ı | 32,7 | 29,0 | 30,8 b-e |
| T7POM1 | 28,1 | 41,3 | 34,7 e-h | 35,6 | 23,0 | 29,3 b-g |
| DİDO | 43,2 | 50,6 | 46,9 b-f | 24,2 | 14,2 | 19,2 e-k |
| HERMES | 28,7 | 25,5 | 27,1 hı | 37,7 | 42,1 | 39,9 ab |
| RUMBA | 35,2 | 36,9 | 36,0 e-h | 26,8 | 29,2 | 28,0 b-h |
| VAN GOGH | 38,7 | 34,2 | 36,4 e-h | 23,0 | 20,0 | 21,5 e-j |
| Mean | 42,0 | 42,9 | 42,4 | 25,4 | 24,9 | 25,1 |
| | $Lsd_{genotype\ (0.01)}$ = 14,3 | | | $Lsd_{genotype\ (0.01)}$ = 13,1 | | |

Browning after frying occurs due to both the reduced sugar content and the interaction of sucrose with the amino acid (Shallenberger et al., 1959). The type of oil used during frying, frying temperature, frying time, fried potato variety affect the color change (Pringle et al., 2009). Many methods are used for color determination after frying. Visual evaluation can be performed by comparing the graphs with the color scales determined by various organizations. This method is cheap, fast, but subjective. These tables are available for French fries (Munsell USDA Frozen French Fries Standard, X-Rite Right On Color) and potato chips (Color Standards Reference Table for Potato Chips, Snack Food Association) (Liu et al., 2009; Pringle et al., 2009). The color scales range from white flesh color to yellow flesh color. Some scales have a large pool of colors ranging from red and purple. Yellow flesh color divided into subgroups such as light yellow, yellow and dark yellow. The yellow color has a higher preference rate in the consumption network. It is in demand because it has a smooth, creamy and sometimes waxy appearance inside when cooked. Tubers that have a white flesh color are usually small-medium sized tubers. Potatoes with low sugar content have a slightly sweetish aroma. The varieties in this scope are suitable to be fried as chips and as finger potatoes (Bond, 2014; Anonymous, 2021c).

Expensive methods that give a clear result can also be used. Fried samples can be determined by wavelengths of the light directed to it via some devices. For example, it can be measured using a color meter such as the Minolta Chroma Meter (Minolta Corp., Ramsey, NJ). The device is calibrated according to the standard white (Minolta) reference plate, the values of L* (whiteness), a* (greenness) and b* (yellowness) can be determined for each sample and it can be evaluated based on the data procured as a result of direct application to the potato surface (Nourian et al., 2003; Pringle et al., 2009).

Table 5
Means of some quality parameters of 30 potato genotypes evaluated under Konya location in 2019-2020 years.

| Genotypes | French fries L* value | | | French fries b* value | | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | Mean | 2019 | 2020 | Mean |
| AFAGR 6 | 38,8 | 31,2 | 35,0 e-j | 18,1 | 29,1 | 23,6 d-g |
| AFAGR7 | 33,6 | 36,4 | 35,0 e-j | 28,1 | 24,5 | 26,3 c-g |
| AFAGR9 | 37,8 | 38,5 | 38,1 d-ı | 23,0 | 23,8 | 23,4 d-g |
| AFAGRB | 38,9 | 39,6 | 39,2 d-ı | 25,4 | 28,2 | 26,8 c-g |
| AFXBRO3 | 42,1 | 35,2 | 38,7 d-ı | 18,4 | 24,9 | 21,6 e-g |
| AFHER3 | 46,8 | 39,1 | 43,0 d-h | 20,4 | 21,1 | 20,7 e-g |
| AFLA5 | 28,5 | 31,9 | 30,2 h-k | 35,7 | 32,5 | 34,1 b-f |
| AFLA11 | 21,6 | 18,4 | 20,0 j-l | 46,7 | 48,7 | 47,7 ab |
| ELAF6 | 25,6 | 27,1 | 26,4 ı-l | 40,9 | 37,5 | 39,2 b-d |
| ELGAF7 | 50,5 | 54,0 | 52,3 b-d | 17,1 | 24,4 | 20,7 e-g |
| GRANAFA | 10,5 | 12,3 | 11,4 l | 58,8 | 57,6 | 58,2 a |
| HERAF6 | 45,8 | 40,9 | 43,4 d-h | 25,2 | 22,9 | 24,0 d-g |
| LOLA1 | 72,7 | 70,3 | 71,5 a | 22,4 | 31,6 | 27,0 c-g |
| POMAFA | 57,4 | 40,9 | 49,1 c-e | 17,8 | 21,5 | 19,6 e-g |
| POMT2/5 | 13,8 | 24,5 | 19,2 kl | 53,3 | 41,9 | 47,6 ab |
| T1AGR1 | 27,1 | 38,0 | 32,6 f-k | 32,2 | 26,1 | 29,1 c-g |
| T1AGR13 | 47,3 | 45,2 | 46,3 d-g | 17,3 | 19,4 | 18,3 fg |
| T3AG2 | 33,9 | 38,5 | 36,2 e-ı | 32,0 | 32,9 | 32,4 b-f |
| T3AG4 | 29,7 | 35,7 | 32,7 f-k | 31,7 | 33,6 | 32,6 b-f |
| T3LA3 | 69,7 | 53,7 | 61,7 a-c | 34,3 | 14,4 | 24,3 d-g |
| T3LA7 | 68,2 | 66,0 | 67,1 ab | 37,8 | 29,5 | 33,7 b-f |
| T3LA10 | 32,0 | 30,6 | 31,3 g-k | 33,4 | 33,8 | 33,6 b-f |
| T3POM2 | 29,4 | 35,3 | 32,4 f-k | 34,7 | 28,6 | 31,6 b-f |
| T3POM6 | 40,1 | 41,8 | 41,0 d-ı | 23,7 | 23,5 | 23,6 d-g |
| T3POM9 | 45,3 | 43,3 | 44,3 d-h | 23,0 | 20,5 | 21,7 e-g |
| T7POM1 | 30,1 | 28,4 | 29,2 h-k | 35,3 | 36,0 | 35,6 b-e |
| DİDO | 34,3 | 30,0 | 32,1 f-k | 32,1 | 35,6 | 33,8 b-f |
| HERMES | 34,1 | 18,0 | 26,0 ı-l | 38,4 | 47,1 | 42,7 a-c |
| RUMBA | 46,2 | 48,2 | 47,2 c-f | 13,9 | 13,2 | 13,5 g |
| VAN GOGH | 38,8 | 32,9 | 35,9 e-ı | 29,2 | 24,2 | 26,7 c-g |
| Mean | 39,0 | 37,5 | 38,3 | 30,0 | 29,6 | 29,8 |
| | $Lsd_{genotype\ (0.01)}$ = 15,3 | | | $Lsd_{genotype\ (0.01)}$ = 16,9 | | |

L* indicates brightness values and b* indicates yellowness values in the color values of the fried samples (Soares et al., 2016). The color values of chips and French fries varied according to the genotype and significant (P <0.01) differences were found. However, the values difference in years and year x genotype interactions was found to be statistically insignificant (Table 2). The average L* brightness values of the chips procured as a result of frying the genotypes differed significantly, the brightest chips L* values were detected in the LOLA1 line with 67.1 and in the AFHER3 line with and 64.4 (Table 4). The dry matter ratios in these lines were determined more than 18 % (Table 3). In the French fry values, the LOLA1 line represented the highest L* brightness value with 71.5 (Table 5). Since tubers with low dry matter ratios will absorb more oil during frying, their L* brightness values also decrease with the same ratio (Ozcan, 2019).

When the b* yellowness values of tubers were examined, significant (P <0.01) differences were detected between the genotypes. According to the b* yellowness values of the tubers, the highest value was determined in the AFLA11 line (44.8) (Table 4). Finger potato b* yellowness values were recorded on the GRANAFA line with 58.2.

It is desirable that the potatoes that will be used as industrial potatoes, French fries (fried potatoes) and potatoes used for making chips have a high productivity. In addition, the fact that they absorb less oil during frying process is a desirable property in terms of both health and low cost. The most important property is the color of chips and French fries. It is desirable that the chips and French fries have a golden-yellow and uniform color (Karadogan, 1994b).

## 4. Coclusion

In our two-year study, lines and standard varieties brought by selection up to the 5th field generation in our potato variety breeding program with high tuber productivities were used and evaluated in terms of quality parameters. Tuber productivity and productivity components are the most important breeding goals in potato breeding studies. In addition, it is important to work with many lines in industrial and edible potato breeding studies and to examine the quality components and agricultural characteristics.

This research aims to determine the promising potato lines by examining the dry matter ratio, frying efficiency, and color scales of the potato lines developed by

Associate Professor Rahim Ada. When the research results were interpreted, T3LA7, T3POM2, T3POM6, T3POM9, AFLA5, LOLA1, T3LA10 lines were determined as ümitvar potato lines in terms of dry matter ratio, frying efficiency and color values.

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# Development of Cigarette Beetle [*Lasioderma Serricorne* (Coleoptera :Anobiidae)] on Spice Plants and Wheat Flour

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**ABSTRACT**

In this study, the development of *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae) was investigated on five different foods (*Mentha piperita, Thymus vulgaris, Salvia officinalis, Rosmarinus, officinalis* and flour). Trials were carried out at a temperature of 28±2°C and 70-75% relative humidity. Effects of foods on development adult longevity and egg hatching ratio of *Lasioderma serricorne* were investigated. As a result, all of the *Lasioderma serricorne* larvae left on the *Rosmarinus officinalis* plant have not completed their development and died. The shortest larval development time was in flour (37.35 days) and the longest in *Mentha piperita* (62.96 days). The shortest Pupal development time was seen in S*alvia officinalis* (4 days), while the longest was seen in *Thymus vulgaris* (4,42 days). *Mentha piperita* (10,50 days) had the shortest adult longevity and was the longest flour (15,5 days). When the egg development time was examined, it was seen that the shortest time was in *Thymus vulgarris* (5,42 days) and the longest time was in flour (5,97 days). The rate of larvae that completed its development was highest in flour (92%) and lowest in *Salvia officinalis* (5%). The rate of pupae that completed its development was highest in flour (80,30%) and lowest in *Salvia officinalis* (37.50%). In the percentages of hatched eggs, it was observed that the lowest opening was in thyme with 56.27% and the highest opening was in flour with 88.89 %.

## 1. Introduction

Cigarette beetle, which is a polyphagous pest, can cause economic damage in many crops grown. Some products such as tobacco and tobacco products, medicinal and aromatic plants (dried herbs, spices, herbal teas, herbariums, dried fruits), flours, cereals, coffee varieties, cocoa, rice, dates, dog food etc. are listed among the hosts of the pest (Cabrera 2002). Especially in warehouse conditions, all these products are under the pressure of *Lasioderma serricorne*. *L. serricorne* on the contaminated product can cause direct by feeding and indirect damage. As a result of intensive feeding on products, they cause weight, seed losses and commercial value. In addition to feeding damage, the presence of dead insects, residues from different life stages such as cast skins or pupal cases, and frass become contaminants in commodities and render them undesirable for human consumption.

In heavy contamination, the host products are completely destroyed. Therefore, if the necessary precautions are not taken, it causes harmful significant economic losses (Da Silva et al 2018).

Life cycle and biological parameters of *L. serricorne* have been investigated in the past under different temperature and relative humidity conditions, generally using flour, tobacco, wheat or yeast as food sources (Jones, 1913; Powell, 1931; Howe, 1957; Mahroof & Phillips, 2008; Kathirvel et al, 2019). Kısmalı & Göktay (1988) reported that the incubation period of eggs which were laid by adults developed on leaf and ground tobaccos were 7.94 and 7.12 days and the larva development time were 50.05 and 52.03 days, respectively. Jones (1913) stated that the average time for the egg development was 6 d, the larval stage was 50 d, and the pupal stage was 12.5 d, when tobacco served as larval food. Powell (1931) determined the length of the life cycle of *L. serricorne* under several controlled temperature and humidity conditions using yeast or tobacco as nutrients. Completion of the life cycle required 18–20 d longer in tobacco than in yeast, for example, at 28 1C and 75% r.h. the development time was 36 d in yeast and 55 d in tobacco. Completion of the life cycle required 18–20 d longer in tobacco than in yeast, for example, at 28°C and

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75% relative humidity. The development time was 36 d in yeast and 55 d in tobacco. Howe (1957) studied the developmental time using wheat as larval food under different temperature and relative humidity conditions. Development times ranged from 5.3 to 20.4 d for eggs 18.2 to 101 d for larvae, 6.4 to 25.9 d for pupae, and 18 to 46 d for adults. Kısmalı & Göktay (1988) reported that the incubation period of eggs which were laid by adults developed on leaf and ground tobaccos were 7.94 and 7.12 days and the larva development time were 50.05 and 52.03 days, respectively.

*L. serricorne*, which is a polyphagous pest, causes damage to many products, especially tobacco. LeCato (1978) stated the time required for development of *L. serricorne* in 19 different spices and the fresh body weights of beetles that emerged from each spice. Among the 19 spices evaluated, paprika (*C. annuum* L.) and cayenne pepper (*Capsicum annuum* L. var. *glabriusculum*) were the most suitable foods for the development of *L. serricorne*. Dimetry et al. (2004) compared six spices and concluded that coriander seeds (*Coriander sativum* L.) were the most favorable host for oviposition. In a recent study to evaluate the variation in responses of male and female *L. serricorne* to various nutrients, products containing wheat, two varieties of tobacco, *Capsicum* spp. and processed almond elicited significantly higher attractive responses by female *L. serricorne* than male beetles (Mahroof and Phillips, 2007). Various studies on this pest have been done before (Allotey & Unanaowo 1993; Ashworth 1993; Atabay et al 2013; Suneethamma 2016; Amoah & Mahroof 2018; Edde 2019; Abd El-Ghany & Abd El-Aziz 2021). However, although there are medicinal and aromatic plants among its hosts, it has been determined that there are very limited studies on this subject (LeCato 1978; Dimetry 2004; Mahroof & Phillips, 2008; Naveena 2019; Kathirvel et al, 2019; El-Fouly et al 2021). In this study, it was aimed to determine the adult longevity, the hatching time and the hatching rate of the eggs, the effects of the development times of larvae and pupae of *L. serricorne* fed on mint, thyme, sage and rosemary plants, which are among the important spice and medicinal-aromatic plants of our country.

## 2. Materials and Methods

Cultures of *L. serricorne*, were maintained in the laboratory of the Plant Protection Department (Faculty of Agriculture of Selcuk University) and grown at a temperature of 28±2°C and humidity of 70-75%. They were reared in 1 liter glass jars by mixing flour and wheat as food.

As food in the experiments; mint (*Mentha piperita*), thyme (*Thymus vulgaris*), rosemary (*Rosmarinus officinalis*), sage (*Salvia officinalis*) and flour were used. The plants were ground into smaller pieces and used in the experiments.

*The effect of foods on the development times of Lasioderma serricorne larvae*

One-day-old larvae were used in the experiment. Mint, thyme, rosamary, sage and flour were placed at the bottom of 2 cm diameter plastic tubes for feeding the larvae. The mouths of the tubes were covered with gauze and placed in the incubator. Each foods source consisted of 4 replications and 25 larvae were used for each repetition. A total of 100 larvae were used for a single food. All studies were carried out in an incubator at 28 ± 2°C and 70-75% RH. Starting from the day of establishment of the experiment, all larvae were checked daily until they turned into pupae. The date of pupae was recorded.

*The effect of foods on the development times Lasioderma serricorne pupae*

Larvae that became pupa after daily controls were separated from other larvae. It was transferred to another plastic tube. The separated 1-day-old pupae were noted with the date of their pupae. For each pupa, the time elapsed between the first appearance of the pupa and the date of adult was determined as the duration of the pupal stage

*The effect of foods on the adult longevity of Lasioderma serricorne*

Three Cigarette beetles (2 male and 1 female) that become adults on the same day were taken from 4 replications of a single food source and a new replication was formed. A total of 10 replications were created from these 3 adults (2 male and 1 female). The day taken from the first day of adult emergence was recorded on each of the plastic tubes. The plastic tubes were checked periodically to observe the adult and the date of death is recorded.

*The effect of foods on the hatching time and hatch rate of Lasioderma serricorne eggs*

The effects of foods on the opening time of the eggs were carried out in parallel with the studies conducted to determine the adult longevity. It was checked everyday whether the female individual lays eggs or not. Eggs laid in the tubes were counted under a stereomicroscope. It was determined whether the larvae hatched. In addition, the hathching period of the eggs (day) was recorded.

*The effect of foods on larval development rates*

The larvae were checked from the first day they hatched, until they turned into pupae. Contents of the tubes were emptied onto a black filter paper and observed daily for live and died larvae. The larval development rate study for each food sources was conducted a total of 100 larvae (4 replications for each food and 25 larvae in each replication).

*The effect of foods on pupal development rates*

The methods used in this experiment were the same as those described for larvae survival ratio. The pupa development rates was found from 100 larvae that completed their development in a healthy way and became adults.

*Statistical analyses*

The research results were evaluated with analysis of variance (ANOVA) and t-test. According to this analysis,

the mean values of the application, which showed a statistically significant difference, were grouped according to the Duncan test. SPSS 21.0 software (SPSS Inc., Chicago, IL, USA) program was used in the statistical assessment of the data.

## 3. Results and Discussion

*The effect of foods on the development times of Lasioderma serricorne larvae*

It was determined that development of *L. serricorne* larvae on rosemary could not complete. For this reason, the effects of other foods (mint, thyme, sage and flour) used in the experiment on the development of the larvae were compared, except for rosemary. Larval development took the longest time in mint (62.96 days), followed by two other medicinal-spice plants, sage (54.77 days) and thyme (49.71 days), respectively. Flour, on the other hand, came after all spice plants (37,35 days) (Table 1).

Among the foods applied, it can be said that the most suitable food for the development of *L. serricorne* larvae is "flour". This faster development could be because of the balanced and essential nutrients present in the wheat. Kısmalı and Göktay (1988) reported that there could be differences in the developmental periods of *L. serricorne* larvae fed on leaf and powder tobacco. While the development period of the larvae fed on powder tobacco was determined as 50.05 days, the development period of the larvae fed on leaf tobacco was determined as 52.03 days. Mahroof and Phillips (2008) revealed that the development of *L. serricorne*, which is fed with seven different foods, in flour (46 days) is shorter than in other foods. El-Fouly et al (2021) stated that the wheat germ was the best preferred food kind for the larval period since the larvae spent the shortest periods (15.36 days). Fenugreek and Chamomile were the less preferred foods of the larval period where was the longest periods 30.55 and 27.09 days, respectively. Therefore, it was concluded that the developmental period of *L. serricorne* larvae was affected by the foods and previous studies also support this result.

Table 1
Development times of *Lasioderma serricorne* larvae grown on different foods.

| Foods | Larval development times (days) | | |
|---|---|---|---|
| | Min. | Max. | Mean ± SE |
| Mint | 34.00 | 77.20 | 62.96 ± 10.03 a * |
| Thyme | 42.75 | 55.66 | 49.71 ± 3.02 ab |
| Sage | 48.00 | 60.00 | 54.77 ± 3.55 ab |
| Flour | 35.72 | 39.61 | 37.35 ± 0.84 b |

*Values in a column followed by different letters are significantly different (P<0.05)

*The effect of foods on the development times of Lasioderma serricorne pupae*

It was determined that the development time of pupae developed on different foods was not statistically different (Table 2).

Since *L. serricorne* larvae could not complete their development on rosemary, pupa formation was not observed on this food. When the development time of the pupae of *L. serricorne* is examined, it is seen that the shortest pupal period is in sage (4 days), and the longest in thyme (4.42 days) (Table 2).

The effect of all foods on pupal development times was limited, and the difference was not statistically significant. In a study conducted by Bozan (1968), it was reported that the development times of the pupae consisting of *L. serricorne* larvae fed on wheat flour, tobacco dust and corn flour were close to each other (8.8 days). El-Halfawy and Nakhla (1976) stated that there was no difference in the development time of *L. serricorne* pupae fed on wheat flour and dry onion at 30°C temperature and 75% RH conditions.

Table 2
Pupal period of *Lasioderma serricorne* grown on different foods

| Foods | Pupal period (days) | | |
|---|---|---|---|
| | Min | Max. | Mean ± SE |
| Mint | 4.0 | 4.20 | 4.05 ± 0.05 a* |
| Thyme | 4.10 | 4.66 | 4.42 ± 0.13 a |
| Sage | 3.00 | 5.00 | 4.00 ± 0.58 a |
| Flour | 3.89 | 4.10 | 4.01 ± 0.46 a |

*Values in a column followed by different letters are significantly different (P<0.05)

Similarly, Kısmalı and Göktay (1988) reported that there was no difference in the development of the pupae formed by *L. serricorne* larvae fed on leaf and powder tobacco. When the previous studies are considered as a whole, it can be concluded that the pupal period of *L. serricorne* does not change according to the foods.

*The effect of foods on the adult longevity of Lasioderma serricorne*

The effect of the foods used in the study on the adult longevity was not statistically significant. The longest adult longevity was recorded for beetles that were reared on flour (15.50 days). This followed by *L. serricorne* adults fed with sage (14.30 days), thyme (13.10 days) and mint (10.50 days), respectively (Table 3). Bozan (1968) stated that different foods have no effect on adult longevity.

Although there was no difference between the mean of adult longevity, all spice plants used as food in the experiment caused a partial decrease in adult longevity (Table 3).

Table 3
Adult longevity of *Lasioderma serricorne* grown on different foods.

| Foods | Adult longevity (days) | | |
|---|---|---|---|
| | Min | Max. | Mean ± SE |
| Mint | 1.00 | 18.00 | 10.50 ± 1.78 a* |
| Thyme | 7.00 | 20.00 | 13.10 ± 1.29 a |
| Sage | 14.00 | 17.00 | 14.30 ± 1.50 a |
| Flour | 11.00 | 19.00 | 15.5 ± 0.79 a |

*Values in a column followed by different letters are significantly different (P<0.05)

*The effect of foods on the hatch time and hatch rates of Lasioderma serricorne eggs*

When the average **hatching time** of the eggs laid by adult females fed with different foods were compared; it was seen that there weren't differences according to foods. However, since adult females fed with mint and sage did not lay any eggs, it was observed not to be any naturally hatch eggs (Table 4). When the thyme and flour on which eggs left were compared, it was seen that the average hatch time of the eggs were extremely close to each other. While the egg hatch time in thyme was 5.97 days, it was determined as 5.42 days in flour. The egg hatch times in flour and thyme were statistically in the same group. There was no statistically significant difference between the hatch times of the eggs in the foods in which eggs were laid. Some researchers reported that there were no significant differences in the hatch times of eggs observed for different foods (Kısmalı and Göktay 1988; Mahroof and Phillips 2008).

Table 4
The hatch time of eggs laid of *Lasioderma serricorne* grown on different foods

| | The hatch time of eggs (days) | | |
|---|---|---|---|
| Food | Min | Max | Mean ± SE |
| Thyme | 5.80 | 6.25 | 5.97 ± 0.14 a |
| Flour | 3.00 | 6.50 | 5.42 ± 0.43 a |

*Values in a column followed by different letters are significantly different (P<0.05)

In addition to the opening hatch times of the eggs laid by the adult females, the hatch ratio of the eggs (%) were also calculated. However, since only the eggs left on flour and thyme were opened, the data of these two foods were evaluated. It was determined that the difference of the hatch ratios of the eggs was related with the foods (Table 5).

Sivik et al. (1957) and Naavena et al. (2019) reported that the hatching percentage was 68.00 % in tobacco and 76.75 % in turmeric powder, respectively.

Table 5
The hatch rates of eggs laid of *Lasioderma serricorne* grown on different foods

| | The egg hatch ratio (%) | | The mean opening rates (%) |
|---|---|---|---|
| Foods | Min | Max | Mean ± SE |
| Thyme | 44.44 | 71.42 | 56.27 ± 7.96 a* |
| Flour | 66.66 | 100 | 88.89 ± 11.11 b |

*Values in a column followed by different letters are significantly different (P<0.05)

*The effect of foods on larval development rates of Lasioderma serricorne*

When the development rate of larvae fed on different food were compared; It was seen that there was a significant difference between the means and this difference was statistically significant (Table 6). The highest pupation rate with 92% was observed in the larvae that fed on flour, it was followed by thyme (63%).

In addition, it was determined that these two foods were in the same group statistically.

Mahroof and Phillips (2008) stated that the larval development ratio according to the foods contained in their research was significantly different. In addition, they stated that the highest larval development ratio was in wheat flour with 92%.

Table 6
Larval development rates of *Lasioderma serricorne* grown on different foods.

| | The larval development rate (%) | | |
|---|---|---|---|
| Foods | Min | Max | Mean ± SE |
| Mint | 4.00 | 32.00 | 18.00 ± 5.77 b* |
| Thyme | 44.00 | 88.00 | 63.00 ± 9.29 a |
| Sage | 0.00 | 8.00 | 5.00 ± 1.91 b |
| Flour | 84.00 | 100.00 | 92.00 ± 9.37 a |

*Values in a column followed by different letters are significantly different (P<0.05)

*The effect of foods on pupal development rates*

When the pupal development rates of *Lasioderma serricorne* larvae fed with different foods were compared; the highest healthy pupal development rate was in the pupae consisting of larvae fed on flour (80.3%). The lowest pupal development rate was found in sage (37.5%). These differences between the means were found to be statistically significant (Table 7).

Table 7
Pupal development rates of *Lasioderma serricorne* grown on different foods.

| | Pupal development rates (%) | | |
|---|---|---|---|
| Foods | Min | Max | Mean ± SE |
| Mint | 25.00 | 100.00 | 60.63 ± 17.63 a* |
| Thyme | 57.14 | 85.71 | 67.25 ± 6.32 a |
| Sage | 0.00 | 100.00 | 37.50 ± 23.94 b |
| Flour | 67.00 | 92.00 | 80.30 ± 5.50 a |

*Values in a column followed by different letters are significantly different (P<0.05)

As with the larval development period and egg trials, the rate of pupa formation from larvae was also negatively affected, especially by sage and mint.

This is in agreement with Kısmalı and Göktay (1988) and Levi et al. (2014) who reported the food affects the healthy pupa formation rate of the larvae.

On the other hand, it is known that spice plants show great variation in terms of the active ingredients they contain. (Smigielski et al. 2018; Fernández-Sestelo and Carrillo 2020) Therefore, it was concluded that there was a great difference in the rate of transition of larvae to pupae depending on the spice plants used in the study. There are many studies in parallel with this results (LeCato 1978; Kim et al. 2003; Lü and Shi 2012; Pino et al. 2013). Therefore, when compared to flour; the fact that spices used as foods adversely affect the development of *L. serricorne* adults, larvae and pupae, in general, and the large variation among the spice plants included in the experiment in terms of their effects on development reveals this may be a result of the difference in the contents of spice plants.

In the study, it was determined that the plants used as food affected the development of *L. serricorne* at a significant level. Our results clearly showed Rosemary cannot be ranked within the food host sequence of *L. serricorne*. Further we confirmed that sage and mint would also be a food in which *L. serricorne* could be found by coincidence, but could not reproduce. It was concluded that the thyme was included in the host sequence of the pest. Therefore, among the spice plants included in the experiment, *L. serricorne* may cause a problem only in thyme (and partially mint), therefore it can be recommended to take precautions especially in terms of Cigarette beetle damage in stored thyme. *L. serricorne* failed to show growth on dried rosemary (and partly sage). Considering the previous studies with different plants, it was concluded that it may be beneficial to test this plant against pests (in terms of insecticidal, repellent or fumigant effect).

If mass production of *L. serricorne* is desired under laboratory conditions, it is recommended to reproduce it in flour. Knowledge of such host use features will be valuable in further research into host selection by *L. serricorne* and may help in the development of pest management systems for this serious pest.

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**Research Article**

# The Use of Different Waste Mulch Materials Against Weeds Which are Problems in Tomato (*Solanum lycopersicum* L.) Cultivation

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**ABSTRACT**

This study was carried out in two different locations (L1: Yüzbaşılar village and L2: TUAM (Iğdır University Agricultural Application and Research Center) in 2020 to determine the effect of different waste mulch materials on weed control and tomato yield. In the study, five different mulch materials (tree of heaven leaves, fine sawdust, wood chips, shredded paper and sheep wool) were used. Each plot has weedy and weed-free control plots. The effects of mulching on weeding suppression, weed dry weight, yield (kg/da), fruit weight (gr) and number of fruit per plant were investigated. Three counts were made to determine the weed density in the plots. As a result of the study, a total of 17 weed species belonging to 9 families were determined in the experimental areas. As a result of the counts, it was observed that *Sorghum halepense* L., *Convolvulus arvensis* L. and *Xanthium strumarium* L. weeds emerged the most in the plots where the mulch materials were applied. Depending on the location, the lowest density among the weed density counts was obtained from the paper plots. In the study, the lowest average weed dry weight among the mulch materials was shredded paper (L1: 97.63; L2: 73.12 gr/m$^2$), the highest average was tree of heaven (L1: 191.87; L2: 165.27 gr/m$^2$) plots. As a result of the study, the best results in tomato yield (L1: 6.078.50; L2: 6.807.87 kg/da) and fruit weight (L1: 142.67; L2: 147.35 gr)) were obtained in the shredded paper mulch applied plots. The highest number of fruits per plant was obtained in the use of wood chips (L1: 45.774.83 pieces) and tree of heaven leaves (L2: 46.627.41 pieces). The fact that mulch applications give better results than control groups suggests that mulches will be much more beneficial for controlling weeds and improving fruit yield and quality.

## 1. Introduction

Turkey is one of the most important crop producer country in the world with its geopolitical position, climatic characteristics and ecological differences. It is one of the rare countries where fruits and vegetables are grown in good and quality conditions with its wide agricultural lands, fertile soils and suitable climate zone crop production. In Turkey, fruits and vegetables are produced in almost every season and in every region. Tomato, is one of the most important vegetables grown, is consumed in different forms as tomato paste, puree, ketchup, tomato juice, dried and fresh tomatoes. The homeland of tomatoes, which ranks first among the most consumed vegetables in the world, is South America.

The first arrival of tomatoes in Turkey was realized through France and Syria in the 19$^{th}$ century (Kaya et al 2018). Turkey ranks 3$^{rd}$ after China and India in world tomato production according to 2020 data (FAO 2020). Amoung the vegetables produced in Turkey tomato is seen the most common one. It comes first in terms of both production area (1.744.372 decares) and production amount (13. 204.015 tons). Tomato production is mostly in Antalya, Bursa and Mersin provinces. In addition, 33.666 tons of tomatoes were produced in Igdir in 2020 (TUIK 2020).

Increasing the amount of product obtained from a unit area in order to meet the food needs of the increasing world population has gained great importance in recent years. With the increase in agricultural production, the amounts of both plant harvest wastes and agricultural industry wastes increase from year to year. These plant-based wastes; In addition to being a good source of organic matter, they also have an important potential in terms of plant nutrients they contain. These wastes are an important source of organic matter, especially for our soils, which are poor in organic matter. Today, these

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wastes can also be used as a plant growing medium by preparing suitable mixtures. Knowing the characteristics of the wastes used will also be useful in increasing the success rate in agricultural production (Citak et al 2007).

Weed species, diseases and pests are the leading plant protection factors that cause yield losses in vegetable production. Weed species compete with vegatablesfor nutrients, water, light, etc. and significantly reducing the yield and quality of vegatables. In addition to this primary damage, it can cause secondary damage by being an intermediate host to many fungal and viral diseases (Uygur et al 1984; Üstüner 2018; Üstüner and Öztürk 2018).

Weeds are one of the biggest problems that cause yields and quality reductions in agricultural areas. It is known that weeds cause great yield losses in tomato, which is widely grown in Turkey in recent years (Tepe 1998). The loss rate of field dodder (*Cuscuta campestris* Yunck.) alone in the yield of Dila pepper (*Capsicum annum* L.); it was calculated as 100% in the seedling stage, 34.22% in the flower stage and 17.02% in the fruit stage (Üstüner 2020). In order to increase yield and quality in tomato cultivation, it is necessary to determine effective, economical, harmless to humans and environment control methods against weeds. One of the methods that can be used to control weeds in tomato production is mulching.

Mulching is covering the soil surface with an opaque material. The aim is to prevent the growing of weeds and to prevent them from photosynthesizing. Although mostly black nylon (polyethylene) covers are used for mulching today, many organic and inorganic materials are also being used. Mulching; preventing weed emergence, preserving moisture in the soil, increasing soil temperature, increasing the amount of nutrients and organic matter in the soil, increasing the number of microorganisms and worms in the soil, providing earliness and yield increase, protecting the soil against erosion, protecting fruits against diseases, increasing fruit quality, dripping irrigation is used which reduces the consumption of water its use in different colors and its positive effect on the fight against insects (Yüksel et al 1992; Buchanan 1999; Edward et al 2000; Koçer & Eltez 2004; Radics et al 2004; Ünlü et al 2006; Koçar 2007).

Compared to the polyethylene covers of various colors, which are widely used in mulching, the demand for organic and inorganic mulching materials has increased today. Among the organic mulches, straw is the most well known. In addition to these, compost, tree bark, husk, leaves, sawdust, paper, etc. obtained from plant residues are used. There are many organic materials that are opaque, abundant and cheap (Kitiş 2011). Organic mulches have both advantages and disadvantages. Advantages; all organic mulches decompose over time, increasing the amount of organic matter in the soil. By creating an environment and a source of food for many living things, they increase the biodiversity. They also have allelopathic effects properties against weeds. Disadvantages; organic mulches can lose their mulch properties in a short period of time because they decompose quickly. In addition, most of them are dispersed by the wind as they are of light structure (Kitiş 2011). One of the organic mulches used for commercial purposes is mulching paper. Mulching paper is an environmentally non-toxic and recyclable organic material containing some vegetable oils and acids. This mulch is cheaper and can be mixed into the soil. However, its sensitivity to tearing and perforation, and rapid disintegration are the major disadvantages of the material (Harrington & Bedford 2004).

In this study; the effects of some organic waste mulch materials were use to control weeds, which are a serious problem in tomato fields, were investigated and it was aimed to present alternative suggestions of herbicides with the results obtained.

## 2. Materials and Methods

The study was conducted in Igdir University Agricultural Application and Research Center (TUAM) (39°55'45.6"N 44°05'42.3"E) and Yüzbaşılar village of Igdir center (40°00'07.3"N 44°04'10.2"E) at two different locations in 2020. Glacier tomato variety was used in the study. The application amounts and general properties of the mulch materials used in the research are given in Table 1. Soil characteristics of the study area are given in Table 2. The climate data of 2020 and mean of long years (MLY) of the months in which the study was carried out are given in Table 3.

Table 1
Mulch materials used in the experiments, application rates and general characteristic

| Treatmets | Application rates | General characteristics |
|---|---|---|
| Fine sawdust | 4.000 kg/da | Poplar wood dust |
| Wood chips | 3.000 kg/da | Poplar wood sawdust waste |
| Sheep wool | 2.500 kg/da | 6 and 12 months old morkaraman lamb's wool |
| Shredded paper | 2.000 kg/da | 1 cm vertically cut sheets of paper |
| Leaves of tree of heaven | 2. 000 kg/da | Tree of heaven freshly plucked leaves |

Table 2
Soil characteristics of the experimental areas

| Soil Properties | Units | L1 | L2 |
|---|---|---|---|
| Profile Depth | cm | 0-30 | 0-30 |
| Constituent Class | - | Clay-Loam | Clay-Loam |
| Lime ($CaCo_3$) | % | 11.32 | 11.05 |
| Total Salt | mmhos/cm | 2 | 2.01 |
| pH | - | 7.9 | 8.1 |
| Phosphorus ($P_2O_5$) | kg $da^{-1}$ | 0.8 | 0.85 |
| Potassium ($K_2O$) | kg $da^{-1}$ | 9.28 | 9.06 |
| Organic Matter | % | 1.8 | 1.85 |

Table 3
Climate data of the year 2020 and MLY (1941-2020) for the months in which the study was carried out (MGM 2020)

| | Average Temperature (°C) | | Total Precipitation (mm) | | Average Relative Humidity (%) | |
|---|---|---|---|---|---|---|
| Months | 2020 | MLY(1941-2020) | 2020 | MLY(1941-2020) | 2020 | MLY(1941-2020) |
| March | 10.44 | 6.2 | 18.1 | 22.1 | 65.6 | 52.2 |
| April | 11.49 | 13 | 83.6 | 33.8 | 76.6 | 49.9 |
| May | 18.8 | 17.7 | 76.1 | 46.5 | 63.1 | 51.5 |
| June | 24.19 | 22.1 | 15.7 | 32 | 48.3 | 47.3 |
| July | 26.7 | 25.9 | 30.2 | 13.7 | 48.4 | 45.3 |
| August | 24.2 | 25.3 | 15.3 | 9.7 | 47.6 | 47.1 |
| September | 23.5 | 20.4 | 1.4 | 11.5 | 47.7 | 46.2 |
| October | 14.5 | 13.1 | 7.3 | 26.3 | 49.6 | 48.53 |

*Tomato Planting, Care and Experimental Set up*

Tomato seedlings were planted on 17.05.2020 with a 80x80 cm inter and intra row spacing. The seedlings were planted along the furrow with 2/3 of their height under the ground and 1/3 above the ground when the soil was annealed. Before planting, 35 kg/da of NPK fertilizer was applied by mixing it into the soil. After planting the seedlings, the first irrigation was done with the drip irrigation system. Afterwards, tomato irrigation was done once a week. In both locations, the study was set up in a randomized complete block design with 4 replications and 7 characters. The size of the plots (4x1.5) was 6 $m^2$, the distance between plots were 0.5 m, and the distance between replications were 1.5 m, and the total experimental area was 325.5 $m^2$. Stake were fixed to the ground for parcellization and rope was used in the strips. The mulch materials in the study were laid on 25.06.2020 with 12 tomato seedlings in each plots. Care was taken not to cover the tomato plants while covering the mulch materials on the inter and intra rows.

*Effect of Mulching on Weed Control*

Weed densities in $m^2$ were asssessed three times in three months (25.07.2020, 25.08.2020, 25.09.2020) in order to determine the effect of different mulch materials (fine sawdust (wood dust), wood chips, sheep wool, shredded paper, tree of heaven leaves) used in tomato cultivation on weed emergence. Hoeing and hand weeding were done together with the emergence of weeds in the weed-free (hoe) plots. In order to determine the density of weeds in the applications, frames of 1 $m^2$ (1x1 m) were used. Weed density values determined for each assessment date were calculated using the following formulas belonging to Odum (1971). According to this; the densities in the applications were determined by dividing the total number of plants determined by the total area counted.

Density = T.Y. / n

T.Y. : Total density of each species in the counted areas (pieces)

n: Counted total area ($m^2$)

As suggested by Üstüner and Güncan (2002), density scale used as follows; Density scale,

A. High dense (average more than 10 weeds / $m^2$)

B. Dense (average 1-10 weeds / $m^2$)

C. Middle dense (average 0.1-1 weeds / $m^2$)

D. Low dense (average of 0.01 to 0.1 weeds / $m^2$)

E. Rare (average of less than 0.01 weeds / $m^2$)

*The Effect of Mulching on Weed Dry Weights*

In both locations, weeds were first assessed on the species basis in order to determine the weed species in the experimental area before the last harvest. Before the last harvest of tomatoes, weeds in all plots were cut from the soil base separately, put in paper bags and brought to the Igdir University Agriculture Faculty of Herbology Laboratory. After being kept in an oven at 70 °C for 24 hours in the laboratory, they were taken and their dry weights were weighed one by one and numerical data were recorded.

*The Effect of Mulching on Tomato Yield and Yield Components*

Tomato harvest were done between 23.07.2020-01.10.2020. Taking into account the market situation at harvest, tomato fruits were picked by hand pulling from the part where the fruit stem meets the branch, and properly plucked. The collected tomato fruits were taken to the Herbology Laboratory of the Faculty of Agriculture of the Sehit Bülent Yurtseven campus of Iğdır University; Fruit weight (g), fruit number per plant (piece/da) and yield (kg/da) values of tomato fruits collected in each plot were determined. The obtained values were compared with the weedy and weed-free (hoe) control plots.

*Data analysis*

As a result of the study, in order to determine the effects of mulching on weed control, weeds dry weight and tomato yield components, Duncan test was applied in SPSS 17.0 Package program and statistical analysis was done and the differences between the applications were evaluated.

## 3. Results and Discussion

*Weed Species Detected in Experimental Areas*

In the experimental areas (L1 and L2), a total of 17 weed species belonging to 9 families, including 1 narrow-leaved, 6 broad-leaved and 1 parasite, were determined. Of the detected weed species, 7 perennial, 9 annual and 1 parasite were determined. In addition,

Brassicaceae (4), Poaceae (3) and Amaranthaceae (3) come first in terms of the number of weeds among the 9 families identified, and least weeds in the families Asteraceae (2), Portulacaceae (2), Polygonaceae (1) and Convolvulaceae (1) has been identified. The distribution of the detected species according to the locations are given in Table 4.

It is seen that the weed species we detected in the results of the experiment are similar to a study conducted with weeds that were a problem in vegetable planting fields and overlap with *C. arvensis*, *C. album*, *Cuscuta* spp, *P. oleracea* and *S. halepense* species (Tepe 1998).

Table 4
Weed species detected in experiment areas

| Family | Scientific Name | Common Name | Life Cycle | L1 | L2 |
|---|---|---|---|---|---|
| Narrow-leaved | | | | | |
| Poaceae | *Sorghum halepense* (L.) Pers. | Johnsongrass | P | × | × |
| | *Setaria verticillata* (L.) P.B. | Bristlegrass | A | × | × |
| | *Cynodon dactylon* (L. ) Pers. | Bermuda grass | P | × | |
| Broad-leaved | | | | | |
| Amaranthaceae | *Chenopodium album* L. | Lambs quarters | A | × | × |
| | *Atriplex nitens* Schkuhr. | Garden orache | A | × | |
| | *Suaeda altissima* (L.) PALL | Seablite | A | × | × |
| Asteraceae | *Cirsium arvense* (L.) Scop. | Californian thistle | P | × | × |
| | *Xanthium strumarium* L. | Rough cocklebur | A | × | × |
| Brassicaceae | *Sinapis arvensis* L. | Wild mustard | A | × | × |
| | *Descurainia sophia* (L.) Webb. Ex Prant. | Flixweed | A | | × |
| | *Cardaria draba* (L.) Desv. | Hoary cress | P | × | × |
| | *Myagrum perfoliatum* L. | Birdseye cress | A | × | × |
| Convolvulaceae | *Convolvulus arvensis* L. | Field bindweed | P | × | × |
| Fabaceae | *Alhagi pseudalhagi* (BIEB.) DESV. | Camel-thorn | P | × | × |
| Portulacaceae | *Portulaca oleracea* L. | Common purslane | A | × | × |
| Polygonaceae | *Polygonum aviculare* L. | Common knotgrass | A | × | |
| Parasite | | | | | |
| Cuscutaceae | *Cuscuta* spp. | Dodder | Parasite | × | × |

Life Cycles; P: Perennial and A: Annual

*The Effect of Applications on Coverage and Weed Density*

In the first assessment made on 25.03.2020 in the plots different mulch materials were applied, it was determined that the highest weed density was in the weed control area (L1: 27.75; L2: 19.25 plant/m$^2$). In the L1 counts, this order is followed by sheep wool (7.25 plant/m$^2$), tree of heaven leaves (7.00 plant/m$^2$), wood chips (5.00 plant/m$^2$), fine sawdust (4.75 plant/m$^2$) and shredded paper (3.00 plant/m$^2$). Differences were observed in the counts in the L2 trial area, and the order was tree of heaven leaves (9.00 plant/m$^2$), fine sawdust (4.75 plant/m$^2$), sheep wool (3.25 plant/m$^2$), shredded paper (2.00 plant/m$^2$) and wood chips (1.50 plant/m$^2$). It was determined that the weed density in the weed-free plot was (L1: 0.00; L2: 0.00 plant/m$^2$). It is seen that the best mulch material is paper in the L1 and wood chips in the L2. (Table 5).

In the 2nd count held on 25.08.2020 in the trial areas; the highest weed density was determined in the weed control plots (L1: 42.00; L2: 38.25 plant/m$^2$). It was seen that sheep wool was mostly (11.00 plant/m$^2$) and shredded paper (4.25 plant/m$^2$) was the least effective mulch in the counts in the L1 plots. In L2 trials; tree of heaven leaves mostly (13.00 plant/m$^2$) and shredded paper (4.50 plant/m$^2$) was least effective mulch.

In the 3rd count held on 25.09.2020 in the L1 and L2, it was determined that the weed density was the highest in tree of heaven leaves plots (L1: 14.00; L2: 16.00 plant/m$^2$). Likewise, it was seen that shredded paper mulch (L1: 8.00; L2: 6.50 plant/m$^2$) was the least effective in the counts. As in both counts, weed density was not observed in the controlled plots without weeds in the 3rd count. It can be said that the results of all counts and waste mulch materials are statistically different from each other. (Table 5). Especially in the 2nd and 3rd counts where the results of weed coating densities were discussed; it is seen that the mulch that suppresses the weeds the most in L1 and L2 plots is the paper material. In a study carried out with tomatoes for 3 consecutive years; rice straw, barley straw, corn harvest residue, wormwood dried, black biodegradable plastic, brown kraft paper, polyethylene and brown kraft paper were used. It has been reported that the most resistant material against weeds is brown Kraft plot (Anzalone et al. 2010). In a study where organic tomatoes were grown and eight different mulch materials were applied, they stated that the best weed control was achieved with paper mulch material (Radics et al 2004). When the findings are compared with the previous studies, it is seen that the results are similar and paper is the best mulch material in weed control.

Table 5
The general covering areas of weeds detected in the plots in the counts

| Treatmets | 1st count (plant/m$^2$) | | 2nd count (plant/m$^2$) | | 3rd count (plant/m$^2$) | |
|---|---|---|---|---|---|---|
| | L1 | L2 | L1 | L2 | L1 | L2 |
| Tree of heaven leaves | 7.00b | 9.00b | 10.75b | 13.00b | 14.00b | 16.00b |
| Fine sawdust | 4.75b | 4.00c | 9.00bc | 5.75c | 11.75bc | 11.00c |
| Wood chips | 5.00b | 1.50cd | 7.75bc | 6.25c | 10.00bc | 12.00c |
| Shredded paper | 3.00bc | 2.00cd | 4.25cd | 4.50c | 8.00c | 6.50d |
| Sheep wool | 7.25b | 3.25cd | 11.00b | 8.75bc | 13.00b | 13.50bc |
| Weedy Control | 27.75a | 19.25a | 42.00a | 38.25a | 48.50a | 46.75a |
| Weed free Control | 0.00c | 0.00d | 0.00d | 0.00d | 0.00d | 0.00e |
| Mean | 7.82b | 5.57 | 12.10 | 10.92 | 15.03 | 15.10 |
| F | 91.7 | 59.82 | 152.23 | 177.75 | 224.12 | 307.30 |
| P | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

*The values in each row and column are statistically different from each other (P≤0.01).

Table 6
Average densities of weed species in L1 and L2 mulch areas

| | Density (plant/m$^2$) | |
|---|---|---|
| Scientific Name | L1 | L2 |
| *Sorghum halepense* (L.) Pers. | 34.15 | 30.3 |
| *Setaria verticillata* (L.) P.B. | 2.25 | 1.75 |
| *Cynodon dactylon* (L. ) Pers. | 3.05 | 0 |
| *Chenopodium album* L. | 0.8 | 0.5 |
| *Atriplex nitens* Schkuhr. | 0.5 | 0 |
| *Suaeda altissima* (L.) PALL | 0.2 | 0.4 |
| *Cirsium arvense* (L.) Scop. | 1.05 | 0.86 |
| *Xanthium strumarium* L. | 6.25 | 4.55 |
| *Sinapis arvensis* L. | 2.15 | 1.25 |
| *Descurainia sophia* (L.) Webb. Ex Prant. | 0 | 0.5 |
| *Cardaria draba* (L.) Desv. | 0.25 | 0.5 |
| *Myagrum perfoliatum* L. | 0.75 | 0.8 |
| *Convolvulus arvensis* L. | 4.25 | 3.75 |
| *Alhagi pseudalhagi* (BIEB.) DESV. | 0.75 | 0.5 |
| *Portulaca oleracea* L. | 0.5 | 0.5 |
| *Polygonum aviculare* L. | 0.2 | 0.2 |
| *Cuscuta* spp. | 0.5 | 0.2 |

When the effect of different mulch materials in tomato against weeding was examined, it was seen that *S. halepense* (L1: 34.15; L2: 30.3 plants/m$^2$) weed species emerged the most as a result of the censuses made in L1 and L2 areas. It has been determined that the least common weeds were *Atriplex nitens*, *Descurainia sophia* and *Polygonum aviculare* and very low emergence in other weeds (Table 6). Jodaugiene et al (2006) investigated the effect on the emergence of weeds using peat, turf, wheat straw, wood chips and wood shavings mulch materials. In the results of their study; they stated that mulching has more effects on annual weed emergence than perennial weeds. In the study conducted with wheat, barley, vetch, clover and canola as mulch plants, they stated that mulch applications in tomato significantly reduced weed density (Kaya and Kadıoğlu 2013). In our study, it is seen that the one-year weed density is less and our results are similar to the studies done.

*Effect of Mulching on Weed Dry Weight*

Duncan multiple comparison test was applied to determine the effect of different waste mulch (tree of heaven leaves, fine sawdust, wood chips, shredded paper and sheep wool) materials used in two different locations (L1 and L2) in tomato cultivation on weed dry weights. According to the results of the analysis, there was a statistical difference of P≤0.01 in terms of weed dry weights between mulch applications (Table 7).

When the effect of different waste mulch materials on weed dry weights in tomato was examined, the highest dry weight was obtained from the weed control plot (L1: 309.40 g/m$^2$ and L2: 254.55 g/m$^2$) in both locations. Among the mulch materials, the lowest weed dry weight is found in paper (L1: 97.63 g/m$^2$ and L2: 73.12 g/m$^2$) and the highest is found in tree of heaven leaves (L1: 191.87 g/m$^2$ and L2: 165.27 g/m$^2$) determined parcels (Table 7). Gurbuz et al. (2021), in the study in which 4 different weed wastes were used as mulch material in eggplant production; it was stated that the lowest weed dry weights were 72.50 g/m$^2$ in *Sorghum halepense* mulch and the highest value was obtained from 525.00 g/m$^2$ weedy control plots. In another study using paper, wheat straw and grass waste mulch materials in tomato production areas; the minimum weed dry weight was obtained from the paper (22 g/m$^2$) plot, and the

maximum weed dry weight were obtained from the weedy check plot (Tülek 2021). Alptekin and Gurbuz (2022) who found the lowest cucumber yield in weedy check plots reported similar results. The results of the study are in agreement with our results and proves that paper mulch is the most effective waste mulch material.

Table 7
Effect of mulching on weed dry weight (g/m$^2$)

| Treatments | L1 | L2 |
|---|---|---|
| Tree of heaven leaves | 191.87b | 165.27b |
| Fine sawdust | 150.70c | 130.55c |
| Wood chips | 127.15c | 145.27bc |
| Shredded paper | 97.63e | 73.12d |
| Sheep wool | 180.55b | 152.47bc |
| Weedy Control | 309.40a | 254.55a |
| Weed Free Control | 0.00f | 0.00e |
| Mean | 151.04 | 131.60 |
| F | 402.53 | 217.66 |
| P | 0.00 | 0.00 |

*The values in each row and column are statistically different from each other (P≤0.01).

*Effect of Waste Mulch Materials on Tomato Yield*

In order to determine the effect of different waste mulch materials on yield in tomato; the number of fruits per plant (pieces), fruit weight (gr), and yield (kg/da) parameters were evaluated. As a result of the measurements and analysis, it was observed that there was a statistically significant difference of 1% (P≤0.01) on the parameters (Table 8).

Compared to the control plots, in the study where different waste mulch materials were used in tomato yield; in both locations, the highest yield was obtained from shredded paper mulch (L1: 6.078.50 and L2: 6.807.87 kg/da). Afterwards, the average yield per plant was taken from wood chips, weed-free control, fine sawdust, sheep wool, tree of heaven leaves and weed control plots, respectively. Yield in L2 trial areas; wood chips, fine sawdust, weed-free control, tree of heaven leaves, wool and weed control plots (Table 8). Karaer (2020), stated that the highest yield was obtained from mulched plots in a 2 year study on tomatoes. Awodoyin et al. (2010) reported that they provided 52-88% yield in tomato yield by using different mulch materials. In a different mulch study, 44% yield was achieved in tomato (Biswas et al. 2015). In the production of tomatoes in India (dried sugarcane leaves, dried poplar leaves, rice straw and wild sugarcane) mulch materials were used to provide yield in tomatoes (Singh 1994). In the studies, it is seen that mulch materials are effective in increasing the yield in tomatoes and the results are similar to our study.

Table 8
The effect of mulching on tomato yield

| | Yield (kg/da) | | Fruit Weight (g) | | Number of Fruits (Number/da) | |
|---|---|---|---|---|---|---|
| Treatments | L1 | L2 | L1 | L2 | L1 | L2 |
| Tree of heaven leaves | 5.229.00c | 5.548.30d | 119.45cd | 119.06de | 43.893.78a | 46.627.41a |
| Fine sawdust | 5.710.27b | 6.131.75c | 127.60bc | 132.32bc | 44.799.48a | 46.447.25a |
| Wood chips | 5.875.20ab | 6.421.70b | 128.35bc | 140.35ab | 45.774.83a | 45.779.56a |
| Shredded paper | 6.078.50a | 6.807.87a | 142.67a | 147.35a | 42.627.89a | 46.206.70a |
| Sheep Wool | 5.567.92bc | 5.431.90d | 122.60c | 118.15de | 45.466.28a | 46.015.86a |
| Weedy Control | 3.817.25d | 4.022.65e | 107.80d | 111.80e | 35.430.94b | 35.978.41b |
| Weed Free Control | 5.826.20ab | 5.917.87c | 135.38ab | 128.33cd | 43.029.59a | 46.110.20a |
| Mean | 5.443.47 | 5.754.57 | 126.26 | 128.19 | 43.003.26 | 44.737.91 |
| F | 96.40 | 260.20 | 19.42 | 30.05 | 18.437 | 39.177 |
| P | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

*The values in each row and column are statistically different from each other (P≤0.01).

The highest tomato fruit weights were obtained from shredded paper mulch plot (L1: 142.67 g and L2: 147.35 g). In L1 plots, this yield was followed by weed-free, wood chips, fine sawdust, sheep wool, tree of heaven leaves and weedy plots, respectively. In the L2, after the paper mulch, the most effective mulches in fruit weight are; wood chips, fine sawdust, weed-free, tree of heaven leaves, sheep wool and weedy control parcels (Table 8). In tomato production (rice straw, kans grass and dencha husk), it increased the fruit yield of organic materials by 21.5-28.8 t/ha (Agarwal 2022). The effects of different soil mulches on field performance, yield and fruit quality of greenhouse tomato (*L. esculentum*) were investigated. The highest yield and large fruits were obtained from compost mulch (Abubaker 2016). The highest effect on the number of tomato fruits in L1 conditions was obtained from rough sawdust (45.774.83 number/da) mulch. In L2 parcels; the best results were obtained from tree of heaven leaves (46.627.41 number/da). The lowest results were obtained from the weed control plots (L1: 35.430.94; L2: 35.978.41 number/da) in both locations. In the study, three different mulches were used in cherry tomato cultivation; the highest fruit yield was obtained from rice straw mulch (Rodríguez Rodríguez 2007). In a different study; it has been reported that organic straw mulch has significant effects on the yield and quality of tomatoes (Ozer 2017). When our results are compared with our control groups; the use of paper mulch in fruit yield and weight; in the number of fruits, it is seen that sawdust and tree of heaven leaves mulches provide a high effect. It can be said that our study findings are similar to other studies results

## 4. Conclusion

In the current study, the most effective waste mulch material in tomato weed control was shredded paper in both locations (L1 and L2). The shredded paper material inhibits photosynthesis by blocking light and slows water uptake, allowing proper penetration of water into

the soil, preventing the emergence and growth of weeds. Shredded paper and other waste mulch materials are cheaper and easier to obtain products for farmers and producers than chemical control and polyethylene mulch. The fact that these products are easily decomposed in the soil and are not harmful to the environment, people and products reveals a good alternative weed control methods. It is thought that these waste products can be used as mulch materials especially in the transplanted tomato crop and in organic agriculture and will contribute to the country's economy.

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**Research Article**

# The Effects of Ortho Silicone Applications on the Acclimatization Process of Grapevine Rootstocks

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**ABSTRACT**

Micropropagation is a tool for large-scale reproduction of planting material for viticulture sustainability. Successful micropropagation depends on the continued productivity of plantlets during the acclimatization phase. Due to high humidity in the culture container and free water in the environment, it causes rapid water loss and drying of plantlets with watery stems and leaves, poorly developed cuticle, large intercellular space, and incomplete stomata. Acclimatization of *in vitro* grown plantlets is often difficult. Silicon is gaining in importance as a useful tool in coping with multiple stress factors in different plant species, due to its contribution to the formation of the cuticle of plants, its mechanical resistance to biotic and abiotic stress, and its contribution to the flow of water through stomata and plant surfaces. In this study, the effects of 500 and 1000 µL ortho silicon applications at the acclimatization stage on *in vitro* propagated plantlets of 41B, 110R and Fercal grapevine rootstocks were evaluated by examining their survival rates. In the *in vitro* propagation process, rooting rates were listed as Fercal (64%) and 110R (32%) and 41B (28%) according to rootstocks, while root numbers were listed as Fercal (11.8), 41B (8.5), 110R (3.6). Genotypic differences were determined in the effects of silicon on plantlets in the acclimation process. In 110R and Fercal control plantlets, all plantlets were lost during acclimatization. Of the plantlets treated with 1000 µL $SiO_2$, 110R 66% Fercal 88% and in 41B, the control, 500 and 1000 µL $SiO_2$ applied plantlets survived 100%, 66% and 66%, respectively. 1000 µL $SiO_2$ dose was more effective on survival rates than 500 µL applications. In subsequent studies, it was found that 1000 µL $SiO_2$ applications could be used for practical success in grapevine genotypes that had problems in acclimatization and in other *in vitro* propagation studies.

## 1. Introduction

Grapevine (*Vitis* spp) is one of the most widely grown species worldwide due to its economic importance (Reynolds 2017). Since its widespread use for the production of wine, table grape and dried grapes, and the beneficial effects of grape metabolites on health, the grapevine is the focus of attention in plant science and a model woody species in plant biotechnology (Yancheva et al. 2018). Commercial grape varieties and grapevine rootstocks are propagated by cuttings and grafting techniques, which require long growing times and are labour intensive. Like other asexual propagated plant species, grapevines are often infected with more than one virus, which reduces crop quality and yield (Choi et al. 2008). Propagation with tissue cultures has recently been applied practically in viticulture to obtain high quality plantlets (Barlass and Skene 1978; Mukherjee et al. 2010; Eftekhari et al. 2012; Jin et al. 2013). In some plant species, the success of the plants propagated in tissue culture is low in greenhouse conditions and then in the stages of transporting them to the open field. This is mainly because of transplant shock, excessive water loss, pathogen attack, poor photosynthesis, etc. This is due to the inability to tolerate different types of stress, such as in plantlets under such stressful conditions, various plant processes such as $CO_2$ assimilation, chlorophyll biosynthesis and water relationships are altered or severely affected (Krishna et al. 2005). Similarly, *in vitro* grapevine propagation studies, a significant part of plantlets cannot maintain their vitality during the acclimation stage to natural environmet (Faulks and Mudge 1988; Kara and Yazar 2020). In previous studies to reduce the problems that occur in the acclimatization process of grapevine and some other plant species, arbuscular mycorrhiza applications (Krishna et al. 2005),

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changing the ambient humidity and plantlet age (Thomas 1998), changing *in vitro* environmental conditions and nutrient content (Kadleček et al. 2001), abscisic acid (Pospíšilová et al. 1998), humic acid and endophytic bacteria applications (Baldotto et al. 2010) were tested.

Bio-stimulators are defined as materials containing one or more active substances and/or microorganisms and are attracting more attention. These substances improve nutrient uptake by plants, tolerance to abiotic and biotic stress (Calvo et al. 2014), and also increase the activity of rhizosphere microorganisms and soil enzymes, as well as stimulate hormone production and photosynthesis (Fageria et al. 2009). Silicon ($SiO_2$) is one of the most popular nanoparticles (NP) materials in the group of synthetic bio-stimulators (Le et al. 2014). $SiO_2$ stimulates the natural immune systems, growth and development of plants and increases tolerance to adverse environmental conditions. $SiO_2$ and its derivatives have beneficial effects on many plant species under both biotic and abiotic stresses. The effects of $SiO_2$-containing Opytsil applications were investigated in the control of some diseases in plants (Hasan et al. 2020), *in vitro* drought stress, in terms of improving physiological and biochemical properties and coping with water stress of plants (Sacala 2009), and its positive effects were noted.

In this study, the effects of ortho silicon (200 g $SiO_2$ $dm^{-3}$) in $SiO_2$ liquid form (Niewiadomska et al. 2020) applied as a foliar spray at doses of 500 and 1000 µL to three grapevine rootstock plantlets during the acclimation period were investigated.

## 2. Materials and Methods

In the study, the shoots from Fercal, 110R and 41B rootstocks in the grapevine rootstock plot belonging to the Selcuk University were cultured as a node culture in the tissue culture laboratory.To obtain suitable material from the grapevine rootstocks grown in the rootstock collection plot, explants were taken during the active development period (Gray and Benton 1991; Di Genova et al. 2014) and single-node micro cuttings were prepared. The study was set up in a randomized plot design with 25 nodes in each plot with 3 replications. For surface sterilization (in a vertical airflow sterile cabinet), the micro cuttings were soaked in 70% ethanol for 2 minutes and then in 12% sodium hypochlorite (NaOCl) solution for 15 minutes and then rinsed 3 times with sterile distilled water. Micro cuttings were placed in jars containing Murashige and Skoog (MS) medium (2% sucrose, 0.7% agar) after surface sterilization (Murashige and Skoog 1962). 1 mg $L^{-1}$ BAP was added to the medium at the beginning and shoot formation stages, and 1 mg $L^{-1}$ IBA was added at the rooting stage. Plant preservative mixture (ppm) was added at a dose of 1 ml $L^{-1}$ to prevent bacterial growth in explants (Kara and Yazar 2020). The explants in the culture medium were placed on shelves with a light source at 3000 lux $m^{-2}$ illumination intensity in the climate room (25±1°C), developed in a 16/8 hour light/dark photoperiod (Notsuka et al. 2000).

The root regions of the plantlets, which were transferred to the rooting medium after the shoot development and whose rooting development were completed, were washed in warm water and treated with fungicide and planted in containers with ReeFlowers Iceland Black Sand (Kara and Yazar 2020).

During the acclimatization phase, 500 and 1000 µL $SiO_2$ doses were applied to the plantlets as a foliar spray for thirty days, repeated five days intervals. Control plantlets were sprayed with pure water only.

### *2.1. Measurements and statistical analysis*

At the beginning of culture, the rate of shooting on 30$^{th}$ day was determined as percent. Rooting rates of plantlets (%) and root numbers per plantlet (pieces plantlets$^{-1}$) were determined in the rooting medium (Mukherjee et al. 2010). One-way analysis of variance of the data obtained from the experiment was performed in a randomized plot design at SPSS 22 statistical program, and compared with Duncan's multiple comparison test at $p<0.05$ significance level (Yue et al. 2017).

## 3. Results and Discussion

*Shooting rate (%)*

*In vitro* micropropagation of Fercal, 110R and 41B rootstocks yielded 100% (Figures 2), rooting differences between rootstock genotypes were insignificant. Contamination is considered a major problem in *in vitro* micropropagation and may cause irreversible damage to the shoot growth medium (Bhojwani and Razdan 1996; Eftekhari et al. 2012). In this study, the optimization of the surface sterilization and the growth-promoting quality of the initial nutrient medium enabled the shooting rate to be 100%.

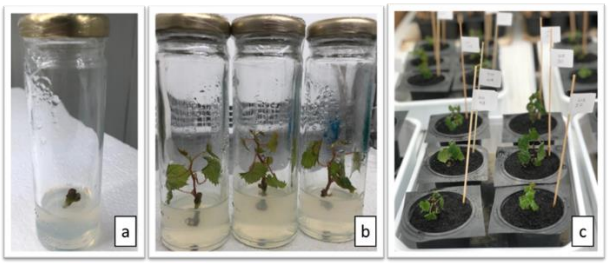


Figure 1
a) explants taken into node culture, b) shoot development stage, c) plantlets transferred to acclimatization medium

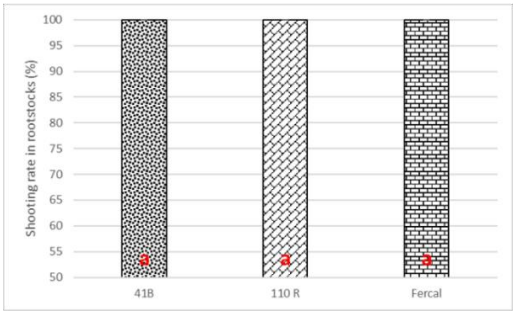


Figure 2
Growth rates (%) of rootstocks in *in vitro* rootstock culture

Contamination is considered a major problem in *in vitro* micropropagation and may cause irreversible damage to the shoot growth medium (Bhojwani and Razdan 1996; Eftekhari et al. 2012). In the study, the optimization of the surface sterilization and the growth-promoting quality of the initial nutrient medium enabled the shooting rate to be 100%.

*Rooting rate (%)*

The difference between rooting rates of rootstocks was significant ($p<0.05$). Although the rooting rates of the plantlets transferred to the rooting medium varied according to the rootstocks, the highest rooting was determined in Fercal (64%), followed by 110R (32%) and 41B (28%) rootstocks (Figure 3).

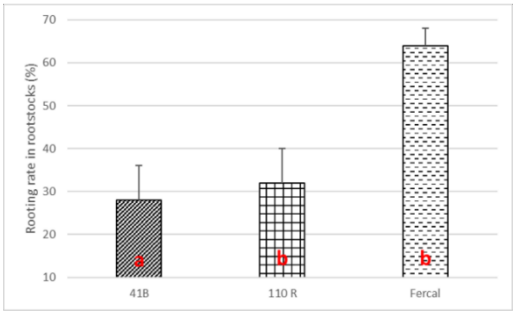


Figure 3
*In vitro* rooting rate (%)

The good rooting and grafting rate of Fercal grapevine rootstock was also reported in previous studies (Laucou et al. 2008). Rooting rates of 41B and 110 R rootstocks are generally low and therefore, silver nanoparticles (Kara et al. 2021), brassinosteroids (Uzunoğlu and Gökbayrak 2018), symbiotic microorganisms (Kara and Başevli 2012), electric current (Kök 2018) and hot water treatment (İşçi et al. 2019) is being tried to be increased as various applications.

*Number of roots (pieces/plantlet)*

Root numbers in plantlets grown in rooting medium were listed as Fercal (11.8), 41B (8.5) and 110R (3.6) (Figure 4). The differences between root numbers of rootstocks were significant ($p<0.05$). Rooting abilities among rootstocks were related to their genetic origins, and the number of roots per plantlets increased in parallel with the rooting rate in Fercal rootstock. Similarly, rooting rates of 41B and 110R rootstocks were low and root numbers were also low, which was considered a genotypic relationship (Galet 1979; Uzunoğlu and Gökbayrak 2018)

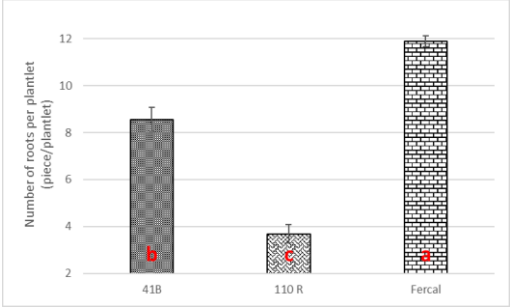


Figure 4
Number of roots (pieces/plantlet)

*Survival rates at the end of acclimation (%)*

The survival rate of plantlets of 41B rootstock was 66.6% in 500 µL and 1000 µL applications, and 100% in the control, with $SiO_2$ applications during the acclimatization phase (Figure 5). In 110R rootstock, plantlet survival at the end of acclimatization was the lowest in the control, followed by 500 µL (33.3%) and 1000 µL (66.6), respectively (Figure 4). Similarly, plantlets in the control group did not survive in Fercal rootstock. Many plantlets survived at 500 µL and 1000 µL treatments (88.8%) compared to control (Figure 4). In 41B, in 500 µL and 1000 µL applications, contamination occurred in some plantlets during the acclimatization phase. For this reason, the plantlets could not maintain their viability and a lower survival rate was obtained compared to the control. A similar result was reported by Barreto and Nookaraju (2007).

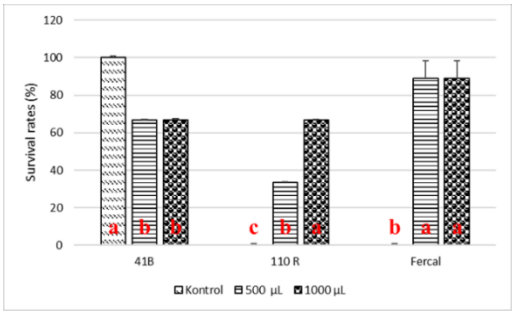


Figure 5
Survival rates (%) of plantlets after acclimatization

Successful micropropagation depends on the sustainability of plantlets at the acclimatization stage. Since plantlets have watery stems and leaves, poorly developed cuticles, large intercellular spaces and incompletely formed stomata due to high humidity in the culture container and free water in the environment, when plantlets are exposed to natural environmental conditions, the problem of drying out is encountered. For this reason, acclimatization of plantlets *in vitro* is often difficult (Savvas et al. 2009; Kamenidou et al. 2010; Whitted-Haag et al. 2014; Lešnik et al. 2017). In a previous studiy report that $SiO_2$ strengthens the cell walls of plants and makes them more resistant to adverse conditions, including low temperature (Ma and Yamaji 2006). It is thought that 500 µL and 1000 µL $SiO_2$ applications increase cell endurance and maintain the vitality of plantlets. $SiO_2$ can affect the metabolism and physiological functions of plantlets, especially under stress conditions. $SiO_2$ is involved in the creation of mechanical or physical barriers in cell walls and intercellular spaces within the cell, reducing the water demand of plants and limiting water loss due to transpiration (Radkowski et al. 2018). At the same time, $SiO_2$ regulates osmosis, provides water balance in plants and positively affects plantlets (Sacala 2009). It is thought that 500 µL and 1000 µL SiO2 applications contribute to the healing of the cuticle layer in poorly developed leaves with the application of Fercal and 110R rootstocks to the plantlets in the acclimatization stage. This is supported by data from applications compared to control (Figure 4). In the current study, it was determined that $SiO_2$

applications showed a satisfactory feature as it limited the stress on plantlets exposed to acclimatization stress and positively affected plant vitality. It can be concluded that $SiO_2$ can produce various metabolites that cause a decrease in transpiration, increase the rate of photosynthesis, affect stomatal conductivity, increase the chlorophyll content and photochemical efficiency of the leaves.

## 4. Conclusion

The results of this study showed that $SiO_2$ applications can be an important tool in dealing with the problems experienced during the acclimatization phase. It is thought that there is a need for further studies examining metabolic functions that will enable us to better understand the interactions between $SiO_2$ application and plant responses.

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**Research Article**

# Reactions of Some Grapevine Rootstock Cuttings to Mutagenic Applications

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**ABSTRACT**

Grapevine (*Vitis* spp.) is one of the most important socio-economically important plants in the global scale, and the need for its breeding is increasing. In viticulture, mutation is more promising than crossbreeding in breeding new genotypes from natural genetic diversity. Polyploid plants outperform their diploid relatives in several respects. In this study, the efficacy of oryzalin and $N_2O$ mutagens in the induction of polyploidy was investigated by applying different doses and durations to the forced cuttings of 41B [Chasselas (*Vitis vinifera* L.) × *Vitis berlandieri* Planch)] and Fercal [(*Vitis vinifera* x *Vitis berlandieri*) × 333 EM] rootstocks. $LD_{50}$ values of mutagen applications were determined, morphological and cytological effects were examined by macroscopic, microscopic, and cytological methods. Application time and dose increase of mutagens decreased $LD_{50}$ values. As a result of mutagen applications, leaf thickness and chlorophyll content of the surviving plants increased. Applications increased stomatal sizes, decreased their density, increased chloroplast numbers, increased leaf thicknesses and partially SPAD values. It was determined that they were not polyploid in the confirmation test performed with flow cytometry (FC) analyses in 4 Fercal and 1 41B samples that were assumed to be mutant by stoma and chloroplast examinations. After that, it was thought that it would be appropriate to try vegetative material with actively dividing cells, such as nodal cuttings, in the studies of obtaining polyploid individuals on grapevine rootstocks

## 1. Introduction

Grapevine (Vitis spp.) is one of the most important socio-economically important plants globally due to the diversity of the products obtained, and there is an increasing demand for its breeding. 77 million tons of grapes are produced from an area surface of 9.9 million hectares in the world. While China ranks first in grape production with 17372167 tons, Turkey ranks sixth with 4.1 million tons of production (Faostat, 2021). The grape market, which was 68 billion dollars in 2016, is the most money-making horticultural crop in the world after tomato (Alston and Sambucci, 2019).

It is thought that the vine has the most variety when compared to other cultivated plant species. In the world, 25538 grapevine genotypes and 1432 grapevine rootstocks are recorded in the Vitis Database (VIVC, 2021). While approximately 10 grapevine rootstock varieties are used in 90% of vineyards worldwide (Keller, 2020), Teleki/Kober selection rootstocks probably constitute 50% of them (Reynolds, 2015). On the other hand, there are many vineyard regions or locations around the world in different climates and different soils. The few rootstock varieties currently used are unlikely to meet the requirements of all viticulture areas (Reynolds, 2015).

Traditional grape breeding poses great challenges to breeders due to the complexity of the traits and the long breeding process of approximately 25 years (Töpfer et al., 2011).

Polyploidy is the presence of more than two genomes per somatic cell. Generally, the polyploid organism has more than one set of chromosomes, or a combination of sets of chromosomes found in the same species, or a closely related diploid species. Polyploid organisms can arise spontaneously (mitotic ploidy) with chromosome copies of somatic cells or in meiosis, with non-segregation of homologous chromosomes giving rise to diploid gametes (Ramsey and Schemske, 2002).

Polyploidy has played an important role in the evolution of higher plants (Leitch and Bennett, 1997). Originally polyploids were thought to have a single origin and assumed genetic uniformity among all individuals of a species. Application of recent molecular biology techniques, particularly DNA markers, has shown that a single polyploid species can have multiple origins,

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suggesting that there is more variation in polyploids than single origin (Soltis and Soltis, 1993; Soltis et al., 1993; Leitch et al. Bennett, 1997; Soltis and Soltis, 1999; Doyle et al., 2004; Soltis et al., 2004; Martelotto et al., 2007).

Successful promotion of polyploidy requires a synergistic coupling of effective penetration of the antimitotic agent and may depend on the exposure time and doses of antimitotic agents, tissue types, basal environment, and interactions with plant growth regulators (Touchell et al., 2020). With the right application time and duration, it can easily penetrate the plant due to the small molecule structure of $N_2O$ and promote polyploidy. In addition, $N_2O$ is not as harmful to nature as colchicine (Kara et al., 2018c).

In this study, the morphological and cytological effects of chemical mutagen applications with the applications of oryzalin and $N_2O$ on the cuttings of 41 B and Fercal rootstocks with different doses and durations to meet the global grapevine rootstock requirement were investigated by macroscopic, microscopic, and cytological methods.

## 2. Materials and Methods

Cuttings containing at least three buds, taken from 41 B [Chasselas (*Vitis vinifera* L.) × *Vitis berlandieri* Planch)] and Fercal [(*Vitis vinifera* x *Vitis berlandieri*) × 333 EM] rootstocks during the resting period and kept in an airtight bag at +1 °C, were used as plant material. The cuttings were placed in pressure resistant tanks and gas flow was provided to the tank through the pressure regulator connected $N_2O$ tube. Various doses (0, 2.5, 5 and 10 bar) and durations (48h-96h) of $N_2O$ were applied to the cuttings with cell division in the phenological development stages 3-5 of Eichhorn and Lorenz (1977). $N_2O$ applied cuttings were planted in cutting rooting pans (peat: perlite, 3:1). For the orzalin application, the cuttings were planted in the pans, 0, 2.5, and 100 µM at the same growth stage were applied twice a day (at 08:30 and 18:00), followed by 48 hours (48h) and 96 hours (96h).

In surviving plants, stomatal density per unit area (number $mm^{-2}$) (Kara et al., 2018c), stomatal sizes (µm) (Kara et al., 2018a), chloroplast numbers in stoma guard cells (number $stoma^{-1}$) (Kara et al., 2018a; Yazar, 2021), leaf thickness, chlorophyll content (Kara et al., 2018b) and Flow Cytometry (FC) analyzes (Yazar, 2018) were done. According to the results of all analysed data, the effects of oryzalin and $N_2O$ treatments on chromosome folding in grapevine were evaluated.

Fresh leaf samples (3-4 weeks) were taken for FC analysis from plants that survived after oryzalin and $N_2O$ application and whose ploidy level was predicted by chloroplast counts. Sections of 0.5 $cm^2$ were taken from the leaf samples, placed in petri dishes, and 500 µL of isolation buffer (Partec-Nuclei Extraction Buffer) was added and the leaf tissue was cut into small pieces with a razor blade. As a result of the lysis process by adding isolation buffer, the cell nuclei were released, and openings were formed on the nuclear membrane. The samples in the Petri dish were shaken for 10-15 seconds and transferred to tubes (Partec-Sample Tubes, 3.5 ml, 55×12 mm) filtered through a Partec-CellTrics 30 µm-green filter. 1600 µL of staining solution [Partec-DAPI (4,6 diamidino-2-phenylindole) Staining Buffer] was added to the tubes, incubated for 5 minutes in a light-isolated environment. Afterwards, the samples were analysed in the FC device (Yazar, 2018).

The data obtained because of oryzalin and $N_2O$ treatment of 41B and Fercal cuttings were compared with the Duncan multiple comparison test in the IBM SPSS 17.0 statistical program (SPSS Inc, Chicago, IL, USA) at $p<0.05$ significance level (Yue et al., 2017).

## 3. Results and Discussion

### *3.1. Survival rate (%)*

The effects of oryzalin and $N_2O$ applications on 41B and Fercal cuttings were significant on the viability rate (Figure 1). Viability rates of 41B cuttings treated with oryzalin were 83.33±5.77%, 46.67±5.77%, 28.33±2.89%, 30.00±5.00 and 11.67±2.89% for control, 25 µM 48h, 25 µM 96h, 100 µM 48h and 100 µM 96h, respectively and the same values were determined in Fercal as 86.67±5.77%, 50.00±5.00%, 46.67±2.89%, 40.00±5.00% and 26.67±2.89%.

The viability rates of $N_2O$ applied 41B for control, 2.5 bar 48h, 2.5 bar 96h, 5 bar 48h, 5 bar 96h, 10 bar 48h and 10 bar 96h applications were 83.33±5.77%, 38.33±2.89%, 25.00±5.00%, 26.67±5.77%, 16.67±2.89%, 21.67±2.89% and 6.67±2.89%, respectively, and in Fercal they were listed as 86.67±5.77%, 46.67±2.89%, 21.67±7.64%, 31.67±2.89%, 13.33±2.89%, 15.00±5.00% and 6.67±5.77%, in the same order. The highest viability of both rootstock cuttings was determined in the control, while the lowest was determined in the application of 10 bar 96h $N_2O$ applications.

Antimitotic agents, especially applied at high concentrations, generally inhibited plant survival (Zakizadeh et al., 2020). In previous studies, oryzalin (Xie et al., 2015) and $N_2O$ (Molenaar et al., 2018) reduced the survival rate. Some researchers have found oryzalin to be highly toxic to plants, especially at higher concentrations and longer exposure times (Dunn and Lindstrom, 2007; Dhooghe et al., 2009). In general, lower concentration and shorter application times decreased the acquisition frequency of tetraploid plants while increasing the survival rate (Chakraborti et al., 1998; Väinölä, 2000; Zhang et al., 2008).

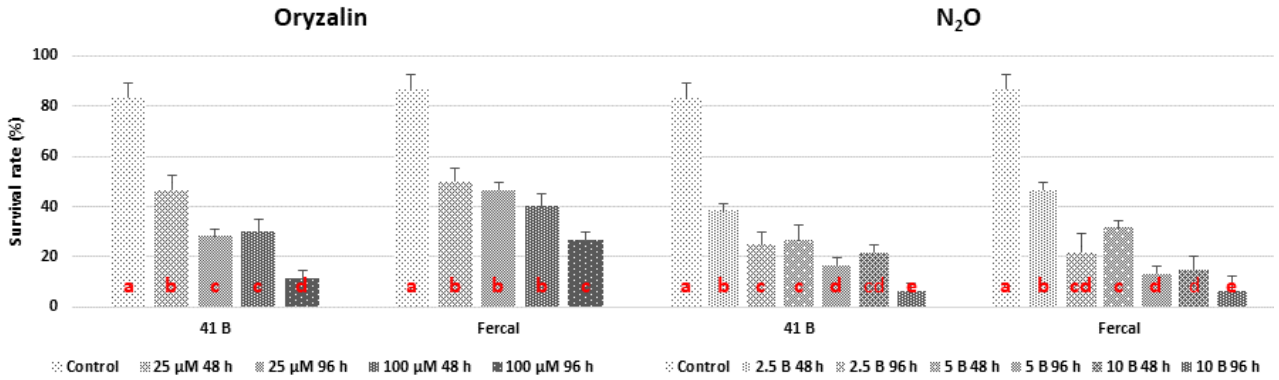


Figure 1
Mutagen effects on the surviving rate of 41 B and Fercal rootstocks

### *3.2. Average lethal dose ($LD_{50}$)*

The $LD_{50}$ values for 48h and 96h were 18.95 µM and 4.12 µM, respectively, in oryzalin applications to 41B. $LD_{50}$ values were recorded as 25.00 µM and 19.84 µM for 48h and 96h, respectively, in the oryzalin applications to Fercal. $LD_{50}$ values decreased with increasing time in applications made to both rootstock cuttings (Figure 2a). The $LD_{50}$ values of $N_2O$ applications were determined as 0.86 bar and 0.39 bar for 48h and 96h applications to 41B cuttings, respectively. The $LD_{50}$ values of $N_2O$ applied Fercal for 48h and 96h were 2.19 bar and 0.18 bar, respectively. In the oryzalin applications, the increase in time decreased the $LD_{50}$ value (Figure 2b).

The $LD_{50}$ values of oryzalin applied 41B were 42.32 hours and 22.53 hours for 25 µM and 100 µM, respectively, and the same values for Fercal were 48 hours and 7.13 hours for 25 µM and 100 µM. In the oryzalin applications, the $LD_{50}$ values were decreased in contrast to the dose increase (Figure 2c).

The LD50 values obtained with $N_2O$ applications to 41B were 26.16 hours, 9.52 hours, and 7.96 hours for 2.5, 5, 10 bar, respectively, and the $LD_{50}$ values in Fercal were 43.75 hours, 24 hours, and 2.61 hours for 2.5, 5 and 10 bar, respectively. Contrary to the increase in $N_2O$ dose, $LD_{50}$ values in the durations decreased in both grapevine rootstocks (Figure 2d).

The mean lethal dose ($LD_{50}$) is often used as a critical parameter for chemical mutagens (Chen et al., 2020). $LD_{50}$ studies evaluate the susceptibility of a mutagen-treated plant part of a particular cultivar to a mutagen (Jain, 2010; Cabahug et al., 2020). Therefore, a series of dose tests is performed to determine which concentration will provide 50% regeneration survival. A series of doses applied in constructing a dose-response curve by examining the data is termed "optimal", where $LD_{50}$ doses and beneficial mutants are reported (Szarejko, 2012).

In previous studies, the $LD_{50}$ value was calculated in two ways. In the first, applications with a 50% mortality rate are given as the $LD_{50}$ value (Asoko et al., 2020; Cabahug et al., 2020; Pehlivan, 2020). In the second, lethal dose-based linear regression was used (Pal et al., 2017; Chen et al., 2020). Time- and dose-dependent $LD_{50}$ value was determined by us by lethal dose-based linear regression method. In our study, $LD_{50}$ values decreased as in previous studies, as in previous studies, in contrast to the application time or dose increase (Kerdsuwan and Te-chato, 2012; Mahajan et al., 2015; Pal et al., 2017; Chen et al., 2020; Hasim et al., 2021).

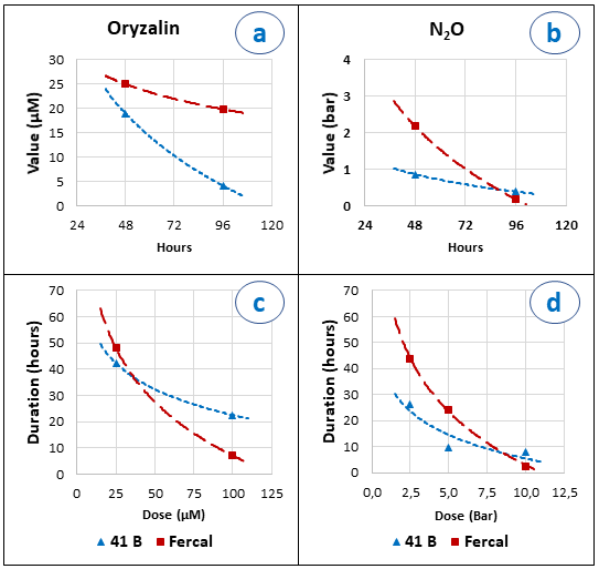


Figure 2
Effects of oryzalin and $N_2O$ treatments on time (a, b) and dose (c, d) dependent $LD_{50}$ values on 41 B and Fercal vine rootstocks.

### *3.3. Stoma density (number $mm^{-2}$) and stoma sizes (µm)*

The effects of oryzalin and $N_2O$ application on the number of stomata in 41B and Fercal were significant. The number of stomata of oryzalin applied 41B were 196.46±2.94, 184.98±6.69, 179.11±3.50, 173.62±3.14, 170.92±2.34 for control, 25 µM 48h, 25 µM 96h, 100 µM 48h and 100 µM 96h, respectively, while it was determined as 196.62±3.82, 187.84±4.63, 173.08±3.50, 173.17±2.71 and 169.61±1.62 units in Fercal, in the same order. In both rootstocks, the densest stomata were detected in the control group, and the lowest density was detected in the application of 100 µM for 96h (Figure 3a).

In $N_2O$ applied 41B, stoma densities were 196.46±3.17, 191.22±2.05 for control, 2.5 bar 48h, 2.5 bar 96h, 5 bar 48h, 5 bar 96h, 10 bar 48h and 10 bar 96h,

respectively, and in Fercal that were 186.79±2.90, 183.49±3.80, 177.27±2.23, 174.92±1.98, 171.08±2.43 were determined as 196.62±3.05, 190.76±2.28, 187.62±2.85, 184.31±2.16, 178.65±2.59, 174.36±2.13 and 171.35±1.61, in the same order. In both rootstocks, the most stoma number was determined in the control, while the least stoma was recorded in the 10 bar 96h application (Figure 3a).

Stomatal lengths in the oryzalin treated 41B were 26.02±0.36 µm, 26.29±0.16 µm, 26.85±0.09 µm, 27.30±0.27 µm, and 27.75±0.25 µm for control, 25 µM 48h, 25 µM 96h, 100 µM 48h and 100 µM 96h applications, and in Fercal that were 26.07±0.24 µm, 26.40±0.55 µm, 26.94±0.19 µm, 28.05±0.17 µm, and 28.53±0.33 µm, in the same order. The highest value was determined at 100 µM 96h in both rootstocks, and the lowest in the control (Figure 3b).

In the $N_2O$ treated 41B, stomatal lengths were 26.02±0.36 µm, 26.34±0.42 µm for control, 2.5 bar 48h, 2.5 bar 96h, 5 bar 48h, 5 bar 96h, 10 bar 48h and 10 bar 96h, 26.61±0.50 µm, 26.94±0.19 µm, 27.48±0.33 µm, 27.81±0.33 µm and 28.22±0.36 µm, respectively. In the Fercal that were 26.07±0.24 µm, 26.40±0.37 µm, 26.73±0.22 µm, 27.08±0.34 µm, 26.91±0.09 µm, 27.31±0.18 µm and 28.12±0.31 µm, respectivelly. The longest stoma was determined in the 10 bar 96h application in both rootstocks, while the lowest stoma was recorded in the controls (Figure 3b).

Effects of oryzalin applications on stomatal width in 41B were recorded as 18.15±0.29 µm, 18.52±0.61 µm, 18.90±0.19 µm, 19.06±0.42 µm, and 18.91±0.27 µm for control, 25 µM 48h, 25 µM 96h, 100 µM 48h and 100 µM 96h, respectively while in Fercal these data were determined as 18.40±0.43 µm, 18.40±0.41 µm, 19.17±0.40 µm, 18.93±0.43 µm and 19.31±0.14 µm in the same order. The largest stomata was in 41B at 100 µM 48h application, and in Fercal 100 µM 96h application. The narrowest stoma was detected in the control in both rootstocks (Figure 3c).

The effects of $N_2O$ applications on stomatal widths in 41B were measured 18.15±0.29 µm, 18.33±0.37 µm, 18.26±0.24 µm, 18.66±0.15 µm, 18.93±0.20 µm, 18.67±0.48 µm, and 19.45±0.28 µm for control, 2.5 bar 48h, 2.5 bar 96h, 5 bar 48h, 5 bar 96h, 10 bar 48h and 10 bar 96h, respectively while in Fercal these values were 18.40±0.43 µm, 18.20±0.29 µm, 18.46±0.25 µm, 18.32±0.18 µm, 18.98±0.24 µm, 19.07±0.26 µm and 19.33±0.45 µm, respectively. The smallest stomata width was detected in 41B control, and in Fercal 2.5 bar 48h application, and the widest at 10 bar 96h in both rootstocks (Figure 3c).

Stoma sizes are an indirect method for identifying polyploids (Moghbel et al., 2015). In general, stomatal characteristics were used for rapid and early identification of polyploids (Cohen and Yao, 1996; Gu et al., 2005; Tang et al., 2010). In addition, the detection of stoma features is simple and does not require expensive instruments. Xie et al. (2015), the most economical and efficient methods for determining the ploidy level are the determination of stomatal sizes and chloroplast numbers, but it was suggested that this method should be applied together with other modern methods for definitive results (Huy et al., 2019).

The variation in stomatal size is one of the most remarkable advanced agronomic features of tetraploid plants (Kosonoy-González et al., 2019). Polyploid plants have larger stomatal sizes and lower stomatal density per unit area than diploid plants (Yang et al., 2006; Lu et al., 2014; Kara et al., 2018c; Bae et al., 2020). This difference is probably due to increased cell size of polyploid plants (Marinho et al., 2014) and/or decreased leaf mesophyll space (Lundgren et al., 2019). Although the stomatal characteristics of the selected plants in our study were like the results of previous studies (Kara et al., 2018a; Zeng et al., 2019; Bae et al., 2020), ploidy could not be confirmed.

### *3.4. Leaf Thickness (µm)*

The effects of mutagen applications on the leaf thickness of 41B and Fercal cuttings at different doses and times were significant. The leaf thicknesses of oryzalin applied 41B were 137.54±5.13 µm, 149.09±4.64 µm, 153.20±3.64 µm, 145.54±4.19 µm, and 156.09±4.83 µm for control, 25 µM 48h, 25 µM 96h, 100 µM 48h and 100 µM 96h, respectively. Leaf thicknesses of Fercal were measured as 136.58±5.00 µm, 134.70±4.14 µm, 150.61±3.55 µm, 153.43±4.48 µm and 159.12±2.25 µm in the same order. In both genotypes, the thickest leaves were detected in 100 µM 96h application, while the thinnest leaves were determined in 41B in control and in 25 µM 48h in Fercal (Figure 4a).

The leaf thicknesses of $N_2O$ applied 41B were 137.54±5.13 µm, 137.68±3.47 µm were 138.60±3.69 µm, 134.80±3.38 µm, 152.35±2.73 µm, 155.91±2.13 µm and 148.90±4.09 µm for control, 2.5 bar 48h, 2.5 bar 96h, 5 bar 48h, 5 bar 96h, 10 bar 48h and 10 bar 96h, respectively, and in the Fercal taht were determined as 136.58±5.00 µm, 140.88±3.24 µm, 136.18±3.75 µm, 138.33±3.22 µm, 144.65±5.04 µm, 142.60±4.58 µm and 151.10±5.24 µm in the same order. As a result of $N_2O$ applications, while the thickest leaves were determined in the application of 10 bar 48h in 41B, the thinnest leaves were detected in the 5 bar 48h hours. In Fercal, the thickest leaves were recorded in 10 bar 48h, the thinnest leaves in 2.5 bar 96h application (Figure 4a).

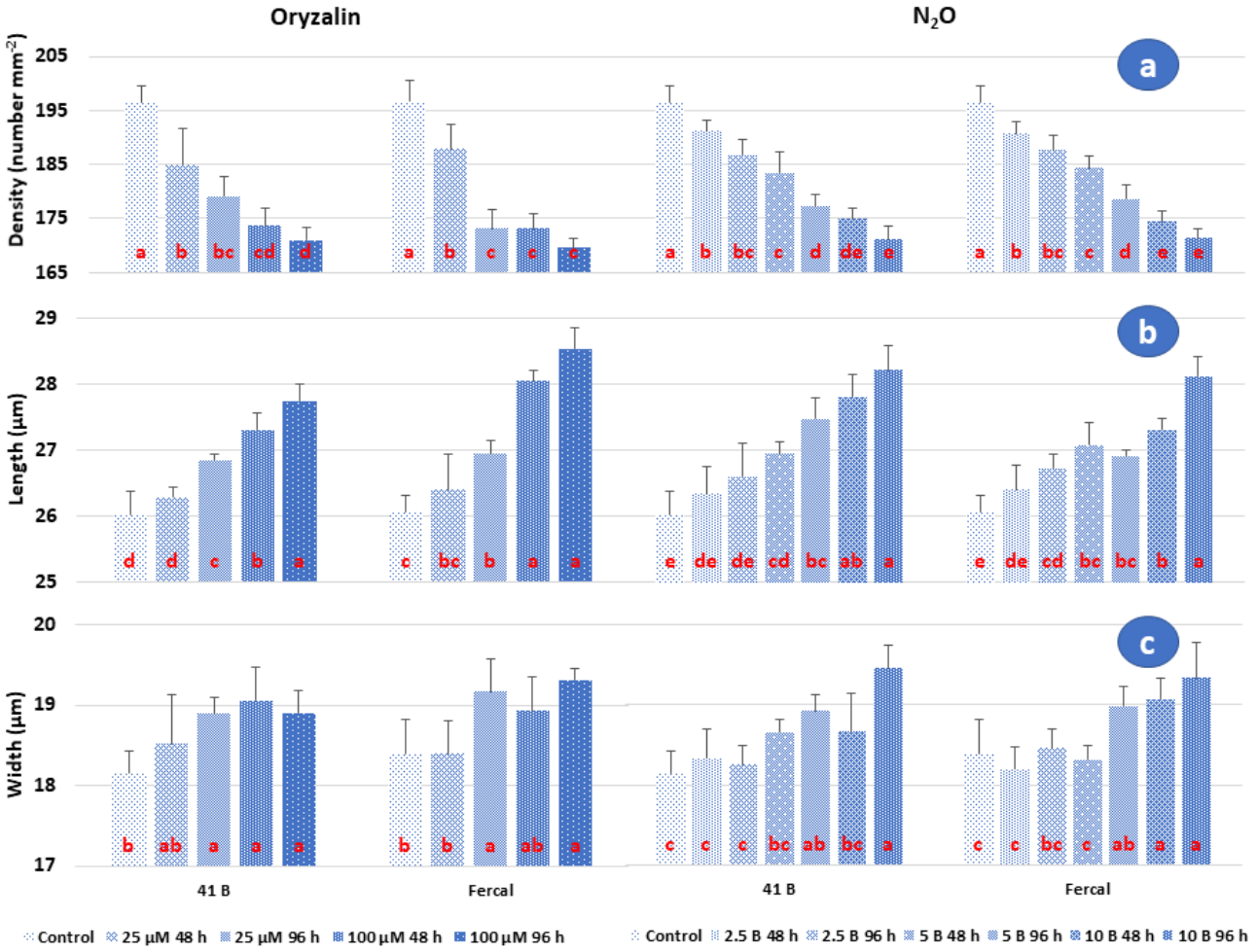


Figure 3
Mutagen effects on stomatal density (a), length (b), and width (c) on 41 B and Fercal rootstocks

Tetraploid plants have wider and thicker leaves than diploids (Rao et al., 2019). In previous studies (Lu et al., 2014; Zeng et al., 2019), leaf thickness of tetraploid plants obtained with oryzalin applications increased compared to their diploid origin. Bae et al. (2020) reported that the leaves of tetraploid plants are smaller, thicker, and wrinkled than their diploids.

*3.5. SPAD Value*

The differences between the chlorophyll content data obtained by the mutagen applications to 41B and Fercal were significant. Chlorophyll content data of oryzalin in 41B was 27.02±0.26, 27.35±0.16, 28.13±0.30, 28.83±0.46 and 32.59±0.33 for control, 25 µM 48h, 25 µM 96h, 100 µM 48h and 100 µM 96h, respectively, and in Fercal that were 27.62±0.57, 25.87±0.12, 27.87±0.10, 28.42±0.42, and 32.78±0.52, respectively. In both rootstocks, the highest chlorophyll content was recorded in 100 µM 96h application, the lowest chlorophyll contents in 41B control and 25 µM 48h application in Fercal (Figure 4b).

Chlorophyll contents in the $N_2O$ treated 41B were 27.02±0.26, 26.77±0.40, 26.29±0.27, 27.93±0.32, 31.73±0.27, 28.95±0.27 and 28.98±0.48 for control, 2.5 bar 48h, 2.5 bar 96h, 5 bar 48h, 5 bar 96h, 10 bar 48h and 10 bar 96h, respectively, in Fercal these values were 27.62±0.57, 27.61±0.43, 27.82±0.42, 26.91±0.22, 31.09±0.34, 31.90±0.86 and 34.16±0.16, respectively. The highest chlorophyll content was determined in 41B at 5 bar 96h, in Fercal at 10 bar 96h, the lowest chlorophyll contents in 41B at 2.5 bar 96h, and at 5 bar 48h in Fercal (Figure 4b).

Herbicides cause whitening (photobleaching) of green tissues by inhibiting the carotenoid biosynthesis pathway, reducing the concentration of coloured carotenoids, and causing photodynamic destruction of chlorophyll molecules (Boger and Sandmann, 1998). On cellular leakage, oryzalin causes some loss of membrane integrity, which is more evident when exposed to light (Dayan and Watson, 2011). The effect of herbicides on plant cells can result in complete loss of microtubules and eventual cell death, not only during mitosis but also during interphase (Yemets and Blume, 2008).

Since herbicides cause photodynamic destruction of chlorophyll molecules and cause green tissues to whiten (photo bleaching), mutagen applications damage chlorophyll molecules (Boger and Sandmann, 1998). Tetraploid plants have higher chlorophyll content compared to diploids and high chlorophyll content can create high photosynthetic capacities (Eng and Ho, 2019).

It was reported in previous studies that the chlorophyll content of tetraploid plants increased compared to diploids (Rao et al., 2019; Mo et al., 2020) found to be significantly less than that of diploids. These differences are thought to be related to the species.

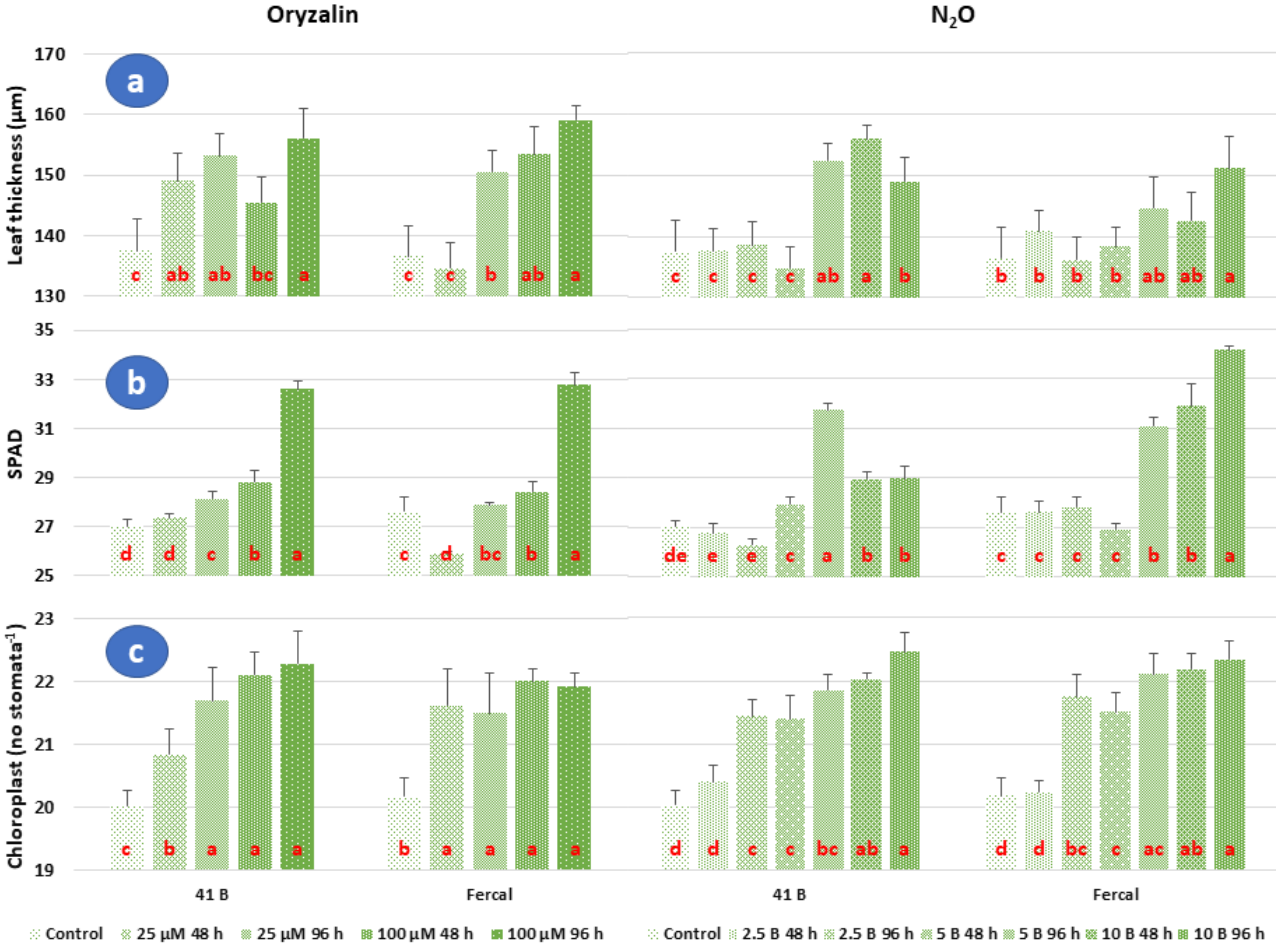


Figure 4
Mutagen effects on leaf thickness (a), SPAD (b), and chloroplast numbers (c) on 41 B and Fercal rootstocks

*3.6. Chloroplast number (number stomata$^{-1}$)*

The effects of mutagen on 41B and Fercal on chloroplast numbers were significant. Chloroplast numbers in oryzalin applied 41B were 20.04±0.23, 20.85±0.40, 21.71±0.53, 22.11±0.36 and 22.30±0.50 for control, 25 µM 48h, 25 µM 96h, 100 µM 48h and 100 µM 96h, respectively. While these values were recorded as 20.18±0.29, 21.63±0.59, 21.50±0.64, 22.01±0.20 and 21.93±0.22 in Fercal, respectively. The least chloroplasts were detected in the control in both rootstocks. 100 µM 96h in 41B, and 100 µM 48h in Fercal caused the most chloroplast increase (Figure 4c).

Chloroplast numbers in the $N_2O$ treated 41B were 20.04±0.23, 20.41±0.25, 21.45±0.27, 21.40±0.38, 21.85±0.26, 22.03±0.11 and 22.46±0.31 for control, 2.5 bar 48h, 2.5 bar 96h, 5 bar 48h, 5 bar 96h, 10 bar 48h and 10 bar 96h, respectively. That were determined in Fercal as 20.18±0.29, 20.24±0.18, 21.76±0.35, 21.51±0.32, 22.11±0.32, 22.18±0.25, 22.34±0.28, respectively. The lowest chloroplast numbers were detected in the control, and the highest chloroplast increase was detected in the 10 bar 96h application (Figure 4c).

Changes in the anatomical features of leaves associated with an increase in cell size in parallel with the increase in ploidy level in plants (Dwivedi et al., 1986) are widely used to evaluate and monitoring the polyploidy promotions (Zhang et al., 2010). In some previous studies, ploidy levels were evaluated according to stomatal length, width, area, and density (Dwivedi et al., 1986; de Carvalho et al., 2005; Yang et al., 2006). Some researchers have reported that the number of chloroplasts per stomatal guard cell is more effective in determining ploidy levels (Compton et al., 1996; Chakraborti et al., 1998; Zhang et al., 2005), however, chloroplast numbers in the stomatal guard cell were found to be similar in diploid and tetraploid plants (de Carvalho et al., 2005). These differences are probably due to the plant species used in the studies (Zhang et al., 2010).

*3.5. Flow cytometry*

Since the chloroplast counts showed polyploidy findings in only 5 plants (4 Fercal and 1 41B) from all treatments, FC analysis was performed to confirm the ploidy levels of these samples. As a result of FC analysis, polyploidy could not be confirmed in the genotypes examined. In FC analyses of diploid control plants and

mutagen treated plants, the peak level was determined around 200 (Figure 5).

FC analysis is a fast, reliable, and simple method to determine the ploidy level and confirm the success of polyploidy induction, and is one of the leading methods, enabling the analysis of large numbers of target plants in a short time (Roy et al., 2001; Dhooghe et al., 2011). Some researchers reported that FC analysis is the most effective and reliable method to detect changes in ploidy level (Dolezel, 1997; Loureiro et al., 2005; Sakhanokho et al., 2009).

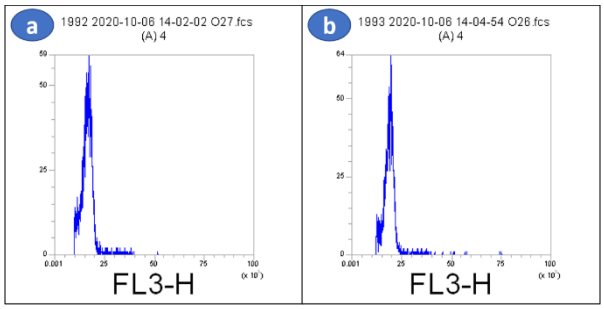


Figure 5
FC analysis result of diploid control plant (a) and mutagen treated and selected 41B sample (b)

## 4. Conclusion

No polyploid individuals could be obtained by *in vivo* applications of oryzalin and $N_2O$ to the cuttings of 41B and Fercal rootstocks. However, $LD_{50}$ values were determined for the effects of mutagens on grapevine rootstocks. These data will be a guide for future studies. Mutagen applications caused a decrease in stomatal densities, stomatal sizes, chloroplast numbers, leaf thickness and SPAD values of rootstock genotypes. Due to the strong DNA damage repair system in grapevine rootstock genotypes, it is thought that the formation of confirmed polyploid grapevine rootstocks is prevented despite preliminary polyploid data. However, to obtain polyploid individuals from vegetative material in grapevine genotypes, it is thought that it would be appropriate to try smaller vegetative shoot and root cuttings, or somatic embryos developed by somatic embryogenesis instead of large size cuttings.

## 5. Acknowledgements

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*Conflict of interest*

Z. Kara, O. Doğan, declare that they have no competing interests.

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**Research Article**

# Effects of Plant Growth Promoting Rhizobacteria on Growth, Yield and Fruit Quality of Pomegranate (*Punica granatum* L.)

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**ABSTRACT**

This study was carried out in a commercial pomegranate garden in Denizli, in 2017-2018 in order to determine the effects of *Pseudomonas sp. HV 5* and *Micrococcus luteus GC- subgroup B MFDV3* bacterial strains, which are potentially capable of improving plant yield and development, on plant growth, yield and quality. The effects of bacterial application on shoot diameter, fruit width, fruit size, fruit juice content, pH, acidity and yield per tree were statistically in significant but the effects on fruit weight, fruit volume and fruit juice C vitamins were found to be significant. Concomitant use of HV5 and MFDV3 bacteria resulted in increased fruit weight, volume, and amount of vitamin C in fruit juice compared to control. According to the results of the research, it was concluded that the bacterial strains used had a positive effect on fruit juice and vitamin C only, so that different application forms and doses should be tested.

## 1. Introduction

Turkey is one of the rare countries where a combination of many types of fruit grown in the world. At present, Turkey is one of the most important producers of many fruit species besides being one of the most production of some fruit species in the world.

Pomegranate, Myrtiflora of the family Punicaceae family, the only genus is Punica. The most important species of this genus is *Punica granatum*. Pomegranate (*Punica granatum* L.) is one of the oldest known fruit species known to humans for 6500 years and is considered a source of healing and healing. It covers the regions of Iran, India, Afghanistan, Anatolia, South Asia, Near East, Middle East and South Caucasus (İkinci, 2007). Pomegranate is a plant which is resistant to arid climate conditions, can adapt to different soil structure in a short time and gives regular product every year. Turkey has a suitable ecology for the cultivation of pomegranate as well as many plant species. World pomegranate cultivation in India, Iran and Turkey are among the first three. Pomegranate production in Turkey has increased very rapidly in recent years. Production, which was 60,000 tons in 2002, reached 465,000 tons in 2016 and 559,000 tons in 2019 (TUİK, 2020). Pomegranate, although grown in almost every region in Turkey, especially in the Aegean and Mediterranean coastline and is cultivated widely in Southeast Anatolia (Özgüven and Yilmaz, 2000). Pomegranate production in Turkey is the highest in Antalya, Muğla, Mersin, Denizli and Adana (TUİK 2020). Turkey, because it is within the boundaries of the homeland pomegranate, shows the richness greatly varieties and forms. There are 48 registered and three pomegranate pomegranate cultivars except for the local types currently grown in Turkey (Anon., 2012).

As a result of the expansion of the pomegranate planting areas, pomegranate production has increased significantly and Turkey pomegranate export has increased significantly. Pomegranate exports, which were $ 9.4 million in 2005, increased by more than 10 times as of 2013 and reached 112 million $. In Turkey among the countries where the pomegranate exports, primarily Russia, Ukraine, Germany, Moldova, including Iraq, Romania, Latvia, Croatia and there are some other countries with Bosnia and Herzegovina (Anon., 2020).

The consumption of pomegranate juice is in the form of pomegranate syrup and its fruits are consumed fresh. In addition, the interest in pomegranate production is increasing all over the world in recent years as it has different usage areas such as tannin, pectin, vinegar, dye and ink raw materials, oil, animal feed and obtaining various pharmaceutical raw materials (Tümer, 2006).

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Pomegranate is used in the treatment of various diseases. It has been reported that pomegranate juice and seed oil prolong life and prevent heart diseases and cancer. Pomegranate juice is good for palpitations. Recently, it has been investigated whether pomegranate juice can be used to combat prostate cancer. In addition, it has been reported in recent years that it is a class of foods used in the treatment of AIDS and is one of the nine plants in Japanese patented drugs (Lansky et al., 1998).

The edible portion of the pomegranate is the seed and its surroundings, this region constitutes 52% of the total fruit, 78% of it is fruit juice and 22% is seed. Juice contains 84.5% water and important amounts of water soluble dry matter, sugar, anthocyanins, phenolics, ascorbic acid and protein (Tümer, 2006). Pomegranate is an anthocyanin rich source. Some compounds found in pomegranate juice, seeds and peel are given as follows (Kim et al., 2002).

There is a search for increasing the amount of production and quality due to the increase in interest of pomegranate. The use of chemical fertilizers and pesticides in fruit growing areas is very limited in a significant part of our country. In organic production, the use of biofertilizers (microbial fertilizers) is becoming widespread. The majority of the bioagens used for this purpose live in the root zone of the plants under the soil. For this reason, these microorganisms are usually used in single-year plants and seeds are seeded with microorganisms. The determination of the effect of microorganisms that can live in sub-soil parts of plants on perennial fruit species and determining formulations that can be transferred to practice are very important for the development of modern and organic fruit cultivation. The aim of this study is to determine the effects of some biological agents (*Pseudomonas* sp. HV5 and *Micrococcus luteus* GC-subgroup B (MFDV3) on pomegranate yield and quality, which can potentially increase plant yield and development.

## 2. Materials and Methods

This study was carried out in Irlıganlı neighborhood of Denizli province between 2017-2018. Hicaz pomegranate cultivars were used as plant material at the age of 6 years.

The soil analysis results of the orchard are given in Table 1. According to the results of the analysis, the amount of organic matter and nitrogen was found to be insufficient. The soil pH was slightly alkaline 8.2. The amount of soil lime was higher.

Table 1
Some physical and chemical properties of the orchard soil (30-60 cm).

| Soil parameters | |
|---|---|
| pH (1:2.5 s:w) | 8.2 |
| EC (µS $cm^{-1}$; 1:5 s:w) | 0.45 |
| Organic matter (%) | 2.37 |
| Lime (%) | 28.8 |
| Clay (%) | 55 |
| Silt (%) | 44 |
| Sand (%) | 1 |
| N (%) | 0.12 |
| P (ppm) | 17.08 |
| K (ppm) | 244 |
| Ca (ppm) | 4.23 |
| Mg (ppm) | 831 |
| Na (ppm) | 170 |
| Fe (ppm) | 12.81 |
| Zn (ppm) | 2.02 |
| Cu (ppm) | 1.02 |
| Mn (ppm) | 10.73 |
| B (ppm) | 2.21 |

Hicaznar pomegranate cultivar with pomegranate berries have a small variety. Its efficiency is very high. Fruit weight is 350 g and fruit width is 91 mm. Fruit shell color is 95% red on yellow background. The grains are dark red in color and 100 grain weight average is 26.1g. It has a tasteful taste close to the sour. It grows well in the coastal and passage regions of the Mediterranean Region (Onur, 1983).

*Pseudomonas* sp. HV5 It was isolated from volcanic soil in Iğdır. The diagnosis of the bacterium was made with the MIDI system used for bacterial characterization. The Diagnostic Sim Index is 38% and is a gram negative strain. Phosphate dissolving and nitrogen fixation is strongly positive.

*Micrococcus luteus* GC- subgroup MFDV3 Iğdır Aralık district was isolated from salty soils. Diagnosis of bacteria was done by MIDI system. Diagnosis Sim Index is 84% and gram positive bacteria. 7.5% NaCl in the medium is a strain that can live.

The bacteria used were obtained from Iğdır University Faculty of Agriculture. Bacterial breeds were planted on Nutrient Agar and stored at 30°C for 24 hours. At the end of this period, the suspension was prepared in 0.1 M phosphate buffer from bacterial cultures. After the bacterial concentration was set at $10^9$ CFU / ml, bacterial suspensions and control application were applied to the crown trace of the trees 3 times in 2 months intervals (Eşitken et al., 2006).

The bacterial applications were planned as randomized plots with 3 replications and 5 trees were used in each replication.

Applications

1. Control

2. HV5; 1 liter was applied to each tree's crown projection by adding 13 liters of water to the bacterial suspension produced as 2 liters. This application was made every two years in April, June and August.

3. MFDV3; 1 liter was applied to each tree's crown projection by adding 13 liters of water to the bacterial suspension produced as 2 liters. This application was made every two years in April, June and August.

4. HV5 + MFDV3; 1 liter of each bacterial suspension and 13 liters of water were added to each tree's crown projection was applied 1 liter each. This application was made every two years in April, June and August.

In this study, plant growth, yield and fruit quality

characteristics were examined as follows:

Fruit weight (g): The average weight of 10 fruits selected from the ripe fruits harvested from each tree is weighed on the balance with 0.01 sensitivity.

Fruit volume ($cm^3$): The volume of 10 fruits selected from each tree is calculated based on the volume of the overflow water.

Measurements of fruit width and length (mm) were made in the largest part of the fruit in the equatorial region of the fruit, with 10 fruits randomly selected from each tree.

Fruit Skin Elasticity (Newton) The elasticity of the fruits was measured by Shoremeter. A 5 mm (0.2 cm) probe was used in the measurement. 1991 Shoremeter ark values between 1-100 shore and 1 Shore = 0.1Newton arasında (Ağar et al., 1991).

The length and diameter of shoots from each tree were measured in mm with the digital caliper.

The amount of total soluble solids (TSS): It was determined as % of the fruits selected from each application by hand refractometer from fruit juice (Yetim, 2001).

Titratable acidity (%): The juice sample was titrated with 0.1 N NaOH to calculate the amount of malic acid (Yetim, 2001).

Vitamin C (mg / 100g) The ascorbic acid content in the samples was determined by spectrophotometric dichlorophenol indophenol method (Pearson, 1976).

The pH of the juice was determined by pH meter.

Yield per plant: The fruits collected from each tree at harvest time were weighed and yield per tree was calculated.

## 3. Results and Discussion

*Results*

*Length and Diameter of Shoot*

The effect of bacterial applications on shoot length was not statistically significant in 2017. In 2018, applications increased the shoot length slightly, but the highest increase was in the implementation of HV5 and MFDV3. In 2018, the length of the shoot was 10.91 mm and it increased to 12.59 mm in the application of 12.18 mm HV5 + MFDV3 in 12.22 mm MFDV3 in HV5 (Table 2). The data obtained are in accordance with the literature in general. Eşitken et al. (2002) stated that OSU-142 bacteria applied to apricot increases shoot length and diameter. At the same time, Eşitken et al., (2006) in their study of BA-8, OSU-142, BA-8 + OSU-142 applications have determined that the length of the shoot increases. Granny Smith apple variety Karlıdağ et al. (2007) in their study in Malatya, the inoculated *Bacillus* M3, *Bacillus* OSU-142 and *Microbacterium* FS01 bacteria were determined to increase the length and diameter of shoots in trees significantly. In another study, 4 bacterial strains regulating plant growth (*Agrobacterium rubi* A-18, *Bacillus subtilis* OSU-142, *Burkholderia gladioli* OSU-7 and *Pseudomonas putida* BA-8) were grafted on MM-106 rootstock. Bacterial applications in the Starkspur Golden Delicious and Golden Delicious apple varieties increased the number of annual shoots and their diameter (Karakurt and Aslantaş, 2010).

Table 2
Effect of bacterial applications on shoot length and diameter

| | Shoot Length (cm) | | Shoot Diameter (cm) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Control | 11.34 | 10.91 b* | 3.56 | 3.46 b |
| MFDV3 | 11.63 | 12.18 a | 3.59 | 3.58 a |
| HV5 | 11.45 | 12.22 a | 3.59 | 3.56 a |
| MFDV3 + HV5 | 11.67 | 12.59 a | 3.57 | 3.54 ab |
| | N.S.** | | N.S. | |

*: Means given within columns followed by a different letter are significantly different at P = 0.05
**: Non-significant

*Fruit Properties*

The effects of the bacterial applications on fruit width were statistically insignificant in 2017 and significant in 2018. In 2018, the highest increase in all fruit cultivars was found in HV5 application with 9.85 cm. In fruit length, there was no significant difference in the application groups in 2017 and 2018 (Table 3). Similarly, Pırlak et al., (2007) in cherry and Eşitken et al. (2006) in apple found that the effect of bacterial applications on fruit diameter was not statistically significant.

The results of the effects of applications on fruit weight are given in Table 3. In 2017, the applications of HV5 and MFDV3 bacteria decreased the fruit weight compared to the control, while the application of these bacteria resulted in an increase in fruit weight. In addition, all applications in 2018 have increased fruit weight. The effect of bacteria on increasing the fruit weight can be attributed to the properties of nitrogen fixation and phosphate removal. Rizobacteria that increase plant growth increase fruit weight in many plant species. As a matter of fact, *Pseudomonas* BA-8 and *Bacillus* OSU-142 bacteria were found to increase plant growth, yield, trunk cross-sectional area, shoot length and fruit weight significantly in the 0900 Ziraat sweet cherry cultivar (Eşitken et al., 2006). In a study carried out in Karaman, *Pseudomonas* BA-8 and *Bacillus* OSU-142 bacterial strains were found to have fruit weight in Starkrimson and Granny Smith apple cultivars (Pırlak et al., 2007). Karlıdağ et al., (2007) in a study conducted in Malatya, *Bacillus* M3, *Bacillus* OSU-142 and *Microbacterium* FS01 radically inoculated bacteria Granny Smith apple varieties have determined that the weight of fruit increases. *Bacillus subtilis* BEB-13bs, which promotes inoculated plant growth in tomato roots, has been found to increase fruit weight (Mena-Violante and Olalde-Portugal, 2007). İpek et al. (2009) found that *Alcaligenes* 637Ca, *Staphylococcus* MFDCa-1, *Staphylococcus* MFDCa-2, *Agrobacterium* A18, *Panteo* FF1 and *Bacillus* M3 bacterial strains, which are compatible with calcareous environments, increased the average fruit weight in Aromas strawberry cultivar by 17.7% compared to control. Shamseldin et al., (2010) in his study of orange Pseudomanas fluorescence 843 strain was used and fruit yield

as well as fruit weight was significantly increased compared to the control. İpek et al., (2014) in his study on strawberry *Alcaligenes* 637Ca fruit weight was increased by 9.4% compared to the control.

Table 3
Effect of bacteria on some fruit properties

| | Fruit Weight (g) | | Fruit Width (cm) | | Fruit Length (cm) | | Fruit Volume ($cm^3$) | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| Control | 460.49 b* | 404.30 b | 9.98 | 9.49 b | 8.56 | 8.23 | 498.12 | 408.33 c |
| MFDV3 | 431.47 c | 436.08 a | 9.89 | 9.72 ab | 8.36 | 8.43 | 497.11 | 455.67 ab |
| HV5 | 447.47 bc | 433.68 a | 9.95 | 9.85 a | 8.49 | 8.32 | 492.44 | 432.67 bc |
| MFDV3+V5 | 498.48 a | 445.42 a | 10.27 | 9.82 a | 8.77 | 8.32 | 501.32 | 464.00 a |
| | | | N.S.** | | N.S. | N.S. | N.S. | |

*Yield*

According to the control of the fruit weight per tree, in terms of yield in 2017 and 2018, no difference was observed according to the control (Table 4.).

Table 4
Yield per tree

| | Yield (kg/plant) | |
|---|---|---|
| | 2017 | 2018 |
| Control | 39.27 | 40.30 |
| MFDV3 | 39.63 | 40.24 |
| HV5 | 39.48 | 40.15 |
| MFDV3 + HV5 | 40.22 | 40.66 |
| | N.S.* | N.S. |

*: Non-significant

In this case, it cannot be mentioned that bacterial applications affect the number of fruits and fruit weight in a positive way. When the yield was compared between 2017 and 2018, no significant difference was observed in both control and application groups. In a study performed by Eşitken et al. (2009), there was no significant effect of OSU-142 bacteria application on yield in Golden Delicious apple. In another study, *Azotobacter chroococcum* nitrogen fusion bacteria and *Glomus mosseae* mushroom combination were used and six years of pomegranate plants showed a significant improvement in the yield of the crops under field conditions (Mir and Sharma, 2012). İpek et al., (2014), *Alcaligenes* 637Ca bacterial strains increased the fruit yield by 47.5% compared to the control in strawberry. Erturk et al., (2012) RC19 (*Bacillus simplex*), RC05 (*Paenibacillus polymyxa*) and RC23 (*Bacillus* spp.) Was radically inoculated and as a result, a significant increase in efficiency compared to the control was observed in Fern strawbeery cultivar.

*Fruit chemical properties*

Bacterial applications do not have a significant effect on the TSS (Table 5). Ipek et al., 2014 in his study of strawberry fruit in the study of rhizobacteria has not seen a significant effect on TSS. Similarly, Eşitken et al., (2006) cherry and Orhan et al. (2006) in raspberry studies on the effects of bacterial applications were found to be insignificant.

In the study, it was found that HV5, MFDV3 and HV5 + MFDV3 applications did not have a significant effect on the fruit juice pH (Table 5).

Fruit juice titratable acidity decreased as a result of the applications, but this decrease was not statistically significant (Table 5). The results are in parallel with the literature. Eşitken et al., (2006) in cherry, Orhan et al., (2006) in raspberry and Pırlak and Köse (2010) in their study of strawberries bacterial applications on the amount of titratable acidity was found to be insignificant.

As a result of the application of HV5, the amount of vitamin C was found to be the same as the control application, while the amount of vitamin C was increased in combination with the application of MFDV3 and bacteria (Table 4.4). The most important source of vitamin C, a water-soluble vitamin, is fresh fruits and vegetables and this increase can be considered as positive. Shamseldin et al., (2010) in their study using *Pseudomanas fluorescence* 843 strain Washington Orange vitamin C concentration was not changed in the first year, but when applied in the second year showed a significant increase compared to control. Ordookhani et al. (2013) reported that an increase in the concentration of vitamin C was induced by the application of plant growth promoting bacteria (*Pseudomonas putida* strain 41, *Azotobacter chroococcum* strain 5 and *Azosprillum lipoferum* strain) to the tomato plant. Erturk et al., (2012) Fern strawberry cultivar RC19 (*Bacillus simplex*), RC05 (*Paenibacillus polymyxa*) and RC23 (*Bacillus* spp.) As a result of the inoculation of vitamin C amount of control according to the control increased with the application of all three rhizobacteria.

Table 5
Effect of Bacterial Applications on Some Fruit Chemical Properties

| | TSS (%) | | pH | | Titratable Acidity (%) | | Vitamin C (mg/100g) | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| Control | 16.63 | 16.25 | 3.12 | 3.13 | 5.74 | 5.65 | 0.45 b | 0.47 b |
| MFDV3 | 16.00 | 16.08 | 3.11 | 3.09 | 4.62 | 4.74 | 0.45 b | 0.48 b |
| HV5 | 15.93 | 15.85 | 3.16 | 3.14 | 4.23 | 4.34 | 0.50 a | 0.52 a |
| MFDV3 + HV5 | 16.50 | 16.77 | 3.13 | 3.11 | 4.36 | 4.29 | 0.56 a | 0.55 a |
| | N.S.** | N.S. | N.S. | N.S. | N.S. | N.S. | | |

*: Means given within columns followed by a different letter are significantly different at P = 0.05
**: Non-significant

*Fruit Skin and Grain Color*

The effects of applications on fruit skin and grain color are given in Table 6. The fruit skin color was determined by Minolta Konica CR-400 cromometer and L, C and Hue values were calculated. L value is the value indicating the brightness of the fruit and this value does not differ according to the control in the MFDV3 and HV5 application. Skin color C value showed significant difference with MFDV3 application. There is no statistical difference in the other groups. Hue value as a result of HV5, MFDV3 and HV5 + MFDV3 applications decreased in all 3 groups. The lowest value according to the control was found in HV5 application with 47.49.

When we look at the results of fruit grain color, L, C and Hue values were determined. Accordingly, L and C values decreased statistically significantly after MFDV3 application. The most serious reduction in C was observed in the combination of bacteria. The Hue value has decreased at the maximum HV5 application.

Table 6
Effect of Bacterial Applications on Fruit Skin and Grain Color

| | Skin Color | | | | | | Grain Color | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | | | 2017 | | | 2016 | | | 2017 | | |
| | L | C | Hue | L | C | Hue | L | C | Hue | L | C | Hue |
| Control | 61.85a | 42.06b | 58.26a | 63.43a | 41.31b | 52.27a | 22.87b | 22.15a | 23.55ab | 23.31b | 21.97a | 23.28a |
| MFDV3 | 60.18 | 42.55b | 46.25d | 59.50a | 42.97b | 47.49d | 24.19ab | 22.48a | 22.31c | 24.02ab | 22.37a | 22.38cb |
| HV5 | 63.58a | 46.85a | 51.44c | 63.39a | 45.65a | 52.40c | 21.67c | 19.85b | 22.95bc | 21.45c | 18.23b | 22.59bc |
| MFDV3 + HV5 | 54.55b | 40.98b | 54.92b | 53.89b | 41.24b | 55.61b | 25.24a | 15.69c | 24.05a | 24.51a | 14.78c | 23.86a |

*: Means given within columns followed by a different letter are significantly different at P = 0.05
**: Non-significant

## 4. Conclusion

In this study, we investigated the effects of HV5 and MFDV3 biochemicals on the growth, fruit yield and properties of pomegranate. As a result of the applications, there are no serious positive and negative effects, and this is due to the fact that the applications do not reach the root area completely. Because, after some applications, sufficient irrigation could not be done, so the bacteria could not reach the root area in full. In addition, the deep rooted roots of the pomegranate plant, which is generally rooted due to irrigation insufficiency, may have prevented the bacteria from reaching. As a result, significant effects in general have emerged in the co-administration of both biosystems. Based on this, it was concluded that more detailed studies on these two bacterial strains as well as bacterial strains that stimulate different growth to be used in organic production in pomegranate plants should be tried.

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**Research Article**

# Doublehaploidization Efficiency of Selected Pepper Genotypes Via in Vitro Anther Culture

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**ABSTRACT**

This study was carried out to determine the effects of genotype and media on haploid plant formation of 12 pepper genotypes (*Capsicum annuum* L.) via *in vitro* anther culture. The buds were cultured in 2 different media (O1 and O2) and, the results revealed that the media had effects on the development of anthers, embryo and plantlet initiation. When the anther developmental status is examined, the lowest value was obtained from the SU-31 genotype with 2.47%, while cv. Flinta F1 produced the highest rate with 12.79%. The highest growth rates were obtained from the O2 medium, and the cv. Dolphin variety produced a remarkable result with 25.0% in this medium. The cultivar Dolphin was the favorable genotypes with 8 embryos and 5 plants, while no embryo and plant were obtained from cv. Flinta F1 and SU-34. A total of 2868 anthers were cultured, 195 anthers were enlarged and the growth rate was 6.8%. Finally, 37 embryos and 18 plants were obtained and the frequencies were 1.29% and 0.63%, respectively. As a result of stomatal observations, 13 plants were detected haploid and the others were double haploid.

## 1. Introduction

Pepper (*Capsicum annuum* L.), whose origin is Central and South America, is a type of vegetable grown economically in Europe since the 15$^{th}$ century and in Turkey since the 16$^{th}$ century. The genus Capsicum includes about 30 species, and *C.annuum*, *C. baccatum*, *C. pubescens*, *C. frutescens* and *C. chinense* are important economically cultivated species. All-natural pepper populations are diploid (2n), with chromosome numbers of 2n=24. Pepper is one of the most consumed vegetable worldwide. The versatile pepper is grown in the open field and protected cultivation at all of the year. It is used in many different forms such as raw, cooked, dried, canned, powdered and chili powder, pepper paste and sauce. World pepper production is 62.7 million tons in 5.33 million hectare areas and the world's top pepper-producing countries are China (19 million tons), Mexico (3.23 million tons), Turkey (2.62 million tons), Indonesia (2.58 million tons) (FAO, 2019). Turkey's pepper production was 2 63 million tons in 77 800 ha, of which 1 291 091 tons of capia pepper (paste), 389 957 tons of bell pepper, 838 890 tons of long green pepper, 116 967 tons of charleston pepper (TUIK, 2020).

Pepper has high economic importance in Turkey and the world; is frequently preferred by breeders in breeding programs. On the other hand, although the seed production of F1 hybrid cultivars used in vegetable growing is more difficult and costly than standard varieties, the reason why F1 hybrid varieties are preferred is that these varieties are more productive than standard varieties, they have wider adaptability and are also resistant to various diseases. Superior varieties can be obtained more quickly with F1 hybrid power (heterosis) breeding. Pepper is known as a highly self-pollinating plant, and the open pollination rate can reach up to 79%.

In classical pepper breeding, it takes a long time to reach a high homozygosity rate in parent lines, but 100% purity cannot be achieved in any way. In addition, the goals that can be reached are limited. Using *in vitro* techniques, 100% homozygous lines can be obtained in a shorter time. Among the *in vitro* techniques the haploid plant production technique, which we can be successful in some species, can have important advantages for breeders. In doblehaploidization (DH) technique, which is one of the *in vitro* techniques used in plant breeding, the aim is to obtain haploid (n) plants originating from the male (anther-pollen culture) and female (ovule-ovary culture) germ cells or parthenogenesis (irradiated pollen

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technique). It is possible to 100% pure (homozygous) doublehaploid plants (2n) by doubling their chromosome numbers with various antimitotic agents. Plants with the number of chromosomes in their somatic cells equal to the number of chromosomes in the gamete cells of the plant species to which they belong are called haploid plants. Since haploid plants contain only one set of chromosomes, they allow recessive mutations to be revealed. To obtain 100% homozygous pure and fertile lines from haploid plants, the chromosome numbers must be doubled (Ellialtıoğlu et al., 2001).

The first doublehaploid pepper lines were obtained from anther culture by Wang et al. (1973) and George and Narayanaswamy (1973). Afterward, studies focused on developing more successful protocols (Dumas de Vaulx et al., 1981; Dumas de Vaulx, 1989). Studies on androgenesis in pepper intensified at the end of the 20th century and studies are continuing intensively today (Rodeva and Cholakov, 2006; Kim et al., 2008; Lantos et al., 2009; Irikova et al. et al., 2011a; Barroso et al., 2015; Çömlekçioğlu et al., 1999; Çömlekcioglu et al., 2001; Ellialtıoğlu et al., 2001; Çiner and Tipirdamaz, 2002; Buyukalaca et al., 2004; Taskin et al., 2011; Al Remi et al., 2014; Arı et al., 2016; Durna, 2016).

Although successful results have been reported in pepper by anther culture in recent years, the number of studies is not intensive and there is still no general protocol reported in all genotypes (Irikova et al., 2011b). The genotype effect, which is one of the most important factors affecting the success in anther culture, still causes the desired response or very low success in many pepper genotypes. In addition, if doublehaploid lines are thought to be used in hybrid pepper cultivar breeding, as many haploid lines as possible are needed. Considering the reasons mentioned above, the level of success achieved in anther culture in pepper today should not be considered sufficient. In this study, which started with this approach, the effects of the medium on *in vitro* androgenetic response of some pepper genotypes were investigated.

## 2. Materials and Methods

### *2.1. Donor Plants*

Eight pepper genotypes (SÜ-29, SÜ-30, SÜ-31, SÜ-32, SÜ-33, SÜ-34, SÜ-35 and SÜ-36) have been collected from our gene pool due to some agronomic characteristics at the S3 stage and 4 commercial pepper cultivars (Klasman F1, Flinta F1, Doru 16 and Dolphin) were used as plant materials. Among the genotypes, "SÜ-29" is Urfa pepper, "SÜ-30", "SÜ-31" and cv. "Klasman F1" are Charleston type, "SÜ-32" and cv. "Flinta F1" are sweet-long type, "SÜ-33" is bitter-long type, "SÜ-34" and cv. "Doru 16" are green-bell type, "SÜ-35" is red-bell type, "SÜ-36" is yellow-bell, and cv. "Dolphin" is capia type.

### *2.2. Cultivation of Donor Plants*

The seeds were sown in plastic boxes containing peat under greenhouse conditions. Seedlings at the stage of 3-4 leaves were planted in greenhouse conditions at 0.7x0.6 m distances, and 20 plants were used for each genotype. After planting, sap water was applied with the drip irrigation system placed in the greenhouse.

The plants were grown healthy by fertilizing twice a week during the plant development period according to the soil analysis. Cultural practices such as weeding, hoeing, and disease and pest management were applied properly and timely. Fruits were discarded continuously, and it was ensured that they produced healthy anthers continuously during the study period.

### *2.3. Determination of Appropriate Microspore Stage in Anthers*

The uninucleate stage in pollen development was determined via the crush-preparation method at the flowering stage. For this purpose, flowers at different developmental stages were collected and the anthers were excised from flowers and were placed on a slide, 1-2 drops of 1% acetocarmine solution were dripped and the anthers were crushed. The samples were examined under the light microscope at 40 x 10 magnification. In this way, anthers containing microspores between the late uninucleate and early binucleate stages were cultured. The size of the buds containing the anthers in this stage was determined, thus the buds at the 3rd and 4th stages were suitable, where the purple color (anthocyanin) was at the tip or up to 1/3 of the anther (Figure 1). Buds at this stage were used thoroughly in the study.

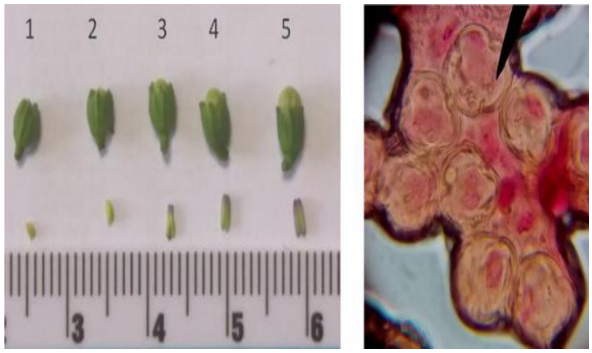


Figure 1
Determination of suitable bud size (left), uninucleate microspores (Right – 400x)

### *2.4. The Media Composition*

The protocols of Taskin et al. (2011) and Arı et al. (2016) were implemented partially modified (Table 1). The media was autoclaved at 121 C°, 1.1 atm for 15 min and poured with an automatic pipette, with 5 ml in each 6 cm diameter sterile Petri dishes under sterile conditions.

Table 1
Media composition

| Media | Composition |
|---|---|
| O1 | MS+0.5 mg/L BAP+4 mg/L NAA+15 mg/L silver nitrate+0.25% activated carbon+30 g/L sucrose+ 8 g/L agar, pH 5.8 (Taşkın et al., 2011). |
| O2 | B5 + 0.5 mg/L BAP + 4 mg/L NAA, + 15 mg/L silver nitrate + 0.25% activated carbon + 30 g/L sucrose + pH 5.8 + 8 g/L agar (Arı et al., 2016) |

*2.5. Surface Sterilization and Anther Preparation*

Buds of appropriate size were collected early in the morning and subjected to surface sterilization for 15 min in a 15% commercial bleach solution. Then the buds were rinsed with sterile distilled water 3 times for 5 min and excessive water was removed with sterile blotting papers. Sterilized buds were carefully opened and filament-free anthers were placed in 6 cm diameter sterile plastic Petri dishes filled with nutrient medium. After the sewing process was completed, the edges of the dishes were closed with stretch films. The anthers were incubated at 35 °C in the dark for 2 days, then were transferred 25 °C and 16/8-h photoperiod.

*2.6. Obtaining Plants and Acclimatization*

Plantlets that started to appear approximately 30 to 60 days after culture and formed cotyledons were taken into germination medium containing MS+0.01 mg/IAA+30 g/L sucrose+8 g/L agar. Plantlets that reached sufficient size were grown in 250 ml jars containing the same medium to complete their development. Plant numbers were multiplied by applying 2-3 micro cuttings for preventing plant losses.

In the process of acclimatization to field conditions, firstly, sterilized peat was filled into plastic cups, and the roots of the plants were removed from the culture medium, and cleaned under tap water, and were planted in 150 ml plastic cups. Before planting, the curled, darkened, and overgrown roots of the plants were discarded, and 1% fungicide solution was added to the sap water to prevent fungal contamination during the acclimatization process. Then, the plants were covered with a plastic bag, and 2 small holes were opened in the bag every two days, and the plants were acclimatized to the field conditions for 2 weeks (Figure 2).

Figure 2
Acclimatization process

*2.7. Determination of Ploidy Status and Dihaploidization Process*

Ploidy determination was realized by stomatal observations (the number of stomata in $mm^2$, the stomata width and length, and the number of chloroplasts in guard cells), which are routinely used in pepper. For this purpose, the lower epidermal parts of the leaves taken from the acclimatized plants were placed on a slide and 1-2 drops of 1% silver nitrate solution were dropped and examined under a microscope. Plants determined to be haploid were planted and grown in 2.5-liter pots filled with 2 peat:1 perlite mixture. *In vivo* colchicine applications were realized at 0.5% concentration for 12 hours. Colchicine solution was applied to axillary buds with immersing method. Thus, the excessive leaves were pruned and a piece of cotton was placed onto the buds and wrapped by aluminum foil. Finally, 1-2 ml of colchicine solution was injected into cotton. The leaves of colchicine applied shoots were examined again by stomatal observations. Colchicine applications were continued to the haploid plants until chromosome doubling was achieved (Figure 3).

Figure 3
Application of colchicine to the haploid plants

In addition, visually ploidy differences were observed in haploid and doublehaploid plants planted in the greenhouse. Although no measurements were made in these observations, it was determined that the development of the vegetative organs of double haploid plants and haploid plants was different, the leaves and flowers of haploid plants were smaller, the plant height was shorter and they developed more slowly.

During the study, the number of anthers cultured (NA), the number of anthers developed callus (NC), the number of developing anthers (NDA), embryo number (EN), embryo frequency (% EF), plant number (PN), plant frequency (% PF) and conversion rate to plant (% CRP) were determined. Since an equal number of materials could not be used for each application statistical analysis could not be realized, only the averages were presented.

## 3. Results and Discussion

During the experiment, a total of 2260 anthers were cultured on O1 and O2 media. The highest anther development rates were obtained from Flinta F1 (15.94%) and cv. Klasman F1 (15.79%), followed by cv. Doru 16 (8.33%). None of the SÜ-31 anthers developed in the O1 medium. In the O2 medium, while anther development was 25.00% in cv. Dolphin, and 16.67% in cv. Doru 16 and SÜ-32, the SÜ-36 genotype had the lowest value (6.94%). Anther development was obtained in O1 and O2 media from all genotypes except SÜ-31 (Table 2).

Table 2
The number of anthers cultured (NA), the number of anthers developed callus (NC), number of developing anthers (NDA)

| Genotypes | Mediums | NA | NC | NDA |
|---|---|---|---|---|
| KLASMAN F1 | O1 | 114 | 18 | 15.79 |
| | O2 | 48 | 6 | 12.50 |
| | ∑ | 162 | 24 | 14.81 |
| FLINTA F1 | O1 | 138 | 22 | 15.94 |
| | O2 | 66 | 11 | 16.66 |
| | ∑ | 204 | 33 | 16.17 |
| DORU16 | O1 | 60 | 5 | 8.33 |
| | O2 | 54 | 9 | 16.67 |
| | ∑ | 114 | 14 | 1.28 |
| DOLPHIN | O1 | 216 | 6 | 2.78 |
| | 02 | 84 | 21 | 25.00 |
| | ∑ | 370 | 27 | 7.29 |
| SÜ 29 | O1 | 102 | 8 | 7.84 |
| | O2 | 114 | 17 | 14.91 |
| | ∑ | 216 | 25 | 11.57 |
| SÜ 30 | O1 | 60 | 1 | 1.67 |
| | O2 | 84 | 6 | 7.14 |
| | ∑ | 144 | 7 | 4.86 |
| SÜ 31 | O1 | 72 | 0 | 0.00 |
| | 02 | 48 | 4 | 8.33 |
| | ∑ | 120 | 4 | 3.33 |
| SÜ 32 | O1 | 192 | 4 | 2.08 |
| | O2 | 66 | 11 | 16.67 |
| | ∑ | 258 | 15 | 5.81 |
| SÜ 33 | O1 | 96 | 7 | 7.29 |
| | O2 | 72 | 6 | 8.33 |
| | ∑ | 168 | 13 | 7.73 |
| SÜ 34 | O1 | 72 | 2 | 2.78 |
| | O2 | 48 | 5 | 10.42 |
| | ∑ | 120 | 7 | 5.83 |
| SÜ 35 | O1 | 102 | 3 | 2.94 |
| | O2 | 72 | 9 | 12.5 |
| | ∑ | 174 | 12 | 6.89 |
| SÜ 36 | O1 | 138 | 9 | 6.52 |
| | O2 | 72 | 5 | 6.94 |
| | ∑ | 210 | 14 | 6.66 |
| | *General* | 2260 | 195 | 8.62 |

Many factors such as the growing period and growing conditions of the donor plant, fertilizing, pre-treatments and genotype affect the anther culture. However, the most important factor is genotype in anther culture (Kristiansen and Andersen, 1993; Qin and Rotino, 1993; Rodeva et al., 2004; Lantos et al., 2009; Nowaczyk et al. et al., 2009; Arı et al., 2016; Durna, 2016; Atasoy, 2020). Nine different pepper genotypes produced different results in embryo formation (Shtereva et al., 1998). Similarly, success in pepper anther culture varies depending on genotypes (Keleş et al., 2015). Our results are following the previous reports, and genotype and medium effect on the fecundity in pepper anther culture.

The embryo and plantlet initiation of pepper genotypes differed depending on the medium. While genotypes resulted in success in embryo formation, there have also been genotypes with low success. Whereas the response of the same genotype to embryo formation in the different medium was high, it could not produce the same success response during the transformation into a plant and its success remained low (Table 3).

Table 3
Embryo number (EN), embryo frequency (% EF), plant number (PN), plant frequency (% PF) and conversion rate to plant (% CRP) according to genotypes and nutrient mediums

| Genotypes | Mediums | EN | EF | PN | PF | CRP |
|---|---|---|---|---|---|---|
| KLASMAN F1 | O1 | 1 | 0.88 | 1 | 0.88 | 100.0 |
| | O2 | 1 | 2.08 | 1 | 2.08 | 100.0 |
| | ∑ | 2 | 1.23 | 2 | 1.23 | 100.0 |
| FLINTA F1 | O1 | 1 | 0.72 | 0 | 0.00 | 0.0 |
| | O2 | 1 | 1.52 | 0 | 0.00 | 0.0 |
| | ∑ | 2 | 0.98 | 0 | 0.00 | 0.0 |
| DORU16 | O1 | 1 | 1.67 | 0 | 0.00 | 0.0 |
| | O2 | 4 | 7.41 | 1 | 1.85 | 25.0 |
| | ∑ | 5 | 4.38 | 1 | 0.87 | 20,0 |
| DOLPHIN | O1 | 2 | 0.93 | 1 | 0.46 | 50.0 |
| | 02 | 6 | 7.14 | 4 | 4.76 | 66.6 |
| | ∑ | 8 | 2.16 | 5 | 1.35 | 62.5 |
| SÜ 29 | O1 | 0 | 0.00 | 0 | 0.00 | 0.0 |
| | O2 | 4 | 3.51 | 3 | 2.63 | 75.0 |
| | ∑ | 4 | 1.85 | 3 | 1.38 | 75.0 |
| SÜ 30 | O1 | 0 | 0.00 | 0 | 0.00 | 0.0 |
| | O2 | 3 | 3.57 | 1 | 1.19 | 33.3 |
| | ∑ | 3 | 2.08 | 1 | 0.69 | 33.3 |
| SÜ 31 | O1 | 0 | 0.00 | 0 | 0.00 | 0.0 |
| | 02 | 2 | 4.17 | 1 | 2.08 | 50.0 |
| | ∑ | 2 | 1.66 | 1 | 0.83 | 50.0 |
| SÜ 32 | O1 | 1 | 0.52 | 1 | 0.52 | 100.0 |
| | O2 | 2 | 3.03 | 1 | 1.52 | 50.0 |
| | ∑ | 3 | 1.16 | 2 | 0.77 | 66.6 |
| SÜ 33 | O1 | 0 | 0.00 | 0 | 0.00 | 0.0 |
| | O2 | 2 | 2.78 | 1 | 1.39 | 50.0 |
| | ∑ | 2 | 1.19 | 1 | 0.59 | 50.0 |
| SÜ 34 | O1 | 0 | 0.00 | 0 | 0.00 | 0.0 |
| | O2 | 0 | 0.00 | 0 | 0.00 | 0.0 |
| | ∑ | 0 | 0.00 | 0 | 0.00 | 0.0 |
| SÜ 35 | O1 | 0 | 0.00 | 0 | 0.00 | 0.0 |
| | O2 | 2 | 2.78 | 1 | 1.39 | 50.0 |
| | ∑ | 2 | 1.14 | 1 | 0.57 | 50.0 |
| SÜ 36 | O1 | 0 | 0.00 | 0 | 0.00 | 0.0 |
| | O2 | 4 | 5.56 | 1 | 1.39 | 25.0 |
| | ∑ | 4 | 1.90 | 1 | 0.47 | 25.0 |
| | *General* | 37 | 1.63 | 18 | 0.79 | 48.6 |

While the highest embryo initiation were obtained from cv. Doru 16 (1.67%), cv. Klasman F1 (0.88%) and cv. Dolphin (0.93%) in O1 medium, SU-36, SU-35, SU-34, SU-33, SU-31, SU-30 and SU-29 gave relatively lower values. Except for SU-31, genotypes that failed in embryo formation continued their anther development, but could not respond to embryo initiation, and some developing anthers only formed callus. Doru 16 (7.41%), Dolphin (7.14%) and SU-36 (5.56%) were the best in O2 medium. Although the SU-34 genotype had a rate of 10.42% in anther development, embryo transformation did not occur.

When the conversion frequencies into plants are compared according to the media, cv. Klasman F1 had the highest frequency with 0.88%, followed by cv. Dolphin (0.46%) and SÜ-32 (0.52%), the other genotypes did not produce any response in the O1 medium. The highest frequency was 4.76% in cv. Dolphin in O2 medium. Although SU-34 and cv. Flinta F1 also formed embryos, the transformation from these embryos to the plant did not occur.

Özsoy (2019) compared MS and B5 media, 209 embryos, 134 plantlets and 57 haploid plants were obtained from MS media, while B5 media produced 218 embryos,

100 plantlets, and 27 haploid plants. It is revealed that MS medium produced the most successful output. However, there are differences between our results and these findings, and this difference is thought to be due to the genotypes and modified MS and B5 media. It is possible to explain these differences between the mediums by the genotype, growing conditions and culture periods.

Previously reports indicated that genotype, media and other factors affect the success of embryo frequency and transformation of embryos into the plants in anther culture (Parra-Vega et al., 2013). Likewise, we determined that success was related to genotype, and anthers cultured in the same period showed different reactions according to genotypes (Karakullukçu and Abak, 1992; Çömlekçioğlu et al., 1999; Çömlekcioglu et al. et al., 2001; Çiner and Tıpırdamaz, 2002; Buyukalaca et al., 2004; Koleva-Gudeva et al., 2007; Taskin et al., 2011). In the present study, it was determined that the conversion rates of the embryos formed into plants were either absent or in small amounts in some genotypes. Although the embryo formation rate in pepper was between 0.5% and 12.5% in anther culture studies, some embryos could not turn into the plants and the conversion rate to plant was 0.5% (Çiner and Tipirdamaz, 2002).

The percentage of development from a total of 1362 anthers cultured in O1 medium was 6.09%, and the embryo frequency was 0.44%, and the plant transformation frequency was 0.22%. Local genotypes 151 and 171 showed positive responses on androgenic embryo formation in MS-based B-series media with a combination of 4 mg/L NAA + 0.1mg/L BAP (Al Remi, 2013). B series media showed similar results with our O1 medium, but the O2 medium gave more positive results. This difference is thought to be due to the different $AgNO_3$ or BAP doses. Moreover, 0.25% activated charcoal had a synergistic effect on embryo initiation depending on the genotype. The percentage of anther developing from 828 anthers cultured in O2 medium was 13.53, and the embryo frequency was 3.74% (Table 4).

Table 4

The number of anthers (NA), the number of developing and callus-forming anthers (NC), the percentage of developing anthers (% PDA), the number of embryos (EN), the embryo frequency (% EF), the number of plants (PN) and plant frequency (% PF)

| Media | NA | NC | PDA | EN | EF | PN | PF |
|---|---|---|---|---|---|---|---|
| O1 | 1362 | 83 | 6.09 | 6 | 0.44 | 3 | 0.22 |
| O2 | 828 | 112 | 13.53 | 31 | 3.74 | 15 | 1.81 |

Transformation frequency from embryos to plant was observed as 1.81%. The O2 media gave much better results than the O1 medium. Although many different plant growth regulators were used in pepper anther culture studies, it was accepted by the researchers that the highest success was obtained from the MS basic nutrient medium using 4 mg/L NAA + 0.1 mg/L BAP + 2.5 mg/L activated carbon. (Çömlekcioglu et al., 2001; Al Remi, 2013). Our findings revealed that the androgenic response of each genotype may vary according to the media. Similar to our findings, the haploidy frequency differed with the media and the genotypes, and the highest androgenic response was determined in the DDVX for the İstek F1 and Al Kırmızı F1, in the MS medium for the Balca F1, and in the B5 medium for the Hızır F1 (Özsoy, 2019).

The ploidy levels of the plants were determined by stomatal (stoma size, number of chloroplasts and number of stomata per unit area) observations (Table 5).

Table 5
Comparison of haploid and doublehaploid plants

| | Haploid | Diploid |
|---|---|---|
| The average number of chloroplasts in guard cells | 7.2 | 10.4 |
| Number of stomata ($mm^2$) | 237.4 | 172.9 |
| Average stoma length and width | 19.08 - 13.81 µm | 30.4 - 19.21 µm |

The mean stomatal dimensions (length and width) were 30.4 µm and 19.21 µm in doublehaploids, while these values were 19.08 µm and 13.81 µm in haploids. The average number of chloroplasts in guard cells was 7.2 in haploid plants and 10.4 in doublehaploid plants. While the number of stomata per unit area ($mm^2$) was 172.9 in diploids and 237.4 in haploids (Figure 4), doublehaploid plants formed larger leaves and plants than haploids (Figure 5).

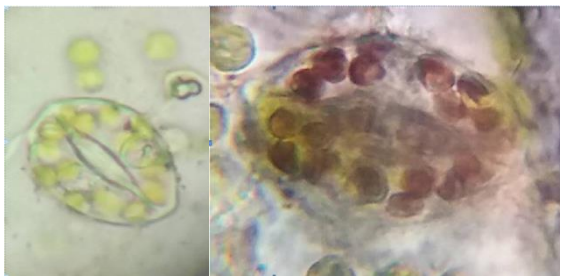

Figure 4
Stomata of haploid (left) and diploid (right) plants (400x)

Figure 5
Haploid (left) and doublehaploid (right) plants

As a result of the stomatal observations (stoma sizes, number of chloroplasts, number of stomata per unit area) of the 18 plants, 13 plants were found to be haploid (n=x=12) and 5 of them were diploid (2n=2x=24). The haploid production efficiency (HPE) was determined according to the criteria of 100 anther/haploid plants (% HPE) and 100 plant/haploid plants (% HPE). SU-29 and Klasman F1 had the highest % HPE values (Table 6).

These results reflected that the success of the anther culture technique is highly correlated with the genotype. Healthy doublehaploid shoots were obtained by applying 0.5% colchicine to the shoot tips and axillary shoots of

the 13 haploid plants propagated by micro cuttings, and fruits and pure seeds were obtained by selfing.

Table 6
Number of anthers cultured (AN), number of plants (PN), number of haploid plants (HPN), number of diploid plants (DPN), haploid production efficiency (% HPE)

| Genotypes | AN | PN | HPN | DPN | % HPE |
|---|---|---|---|---|---|
| Klasman F1 | 162 | 2 | 2 | 0 | 1.23 |
| Flinta F1 | 204 | 0 | 0 | 0 | 0.00 |
| Doru 16 | 114 | 1 | 0 | 1 | 0.00 |
| Dolphin | 370 | 5 | 3 | 2 | 0.81 |
| SÜ-29 | 216 | 3 | 3 | 0 | 1.38 |
| SÜ-30 | 144 | 1 | 1 | 0 | 0.69 |
| SÜ-31 | 120 | 1 | 1 | 0 | 0.83 |
| SÜ-32 | 258 | 2 | 1 | 1 | 0.38 |
| hSÜ-33 | 168 | 1 | 0 | 1 | 0.00 |
| SÜ-34 | 120 | 0 | 0 | 0 | 0.00 |
| SÜ-35 | 174 | 1 | 1 | 0 | 0.57 |
| SÜ-36 | 210 | 1 | 1 | 0 | 0.47 |
| ∑ | 2260 | 18 | 13 | 5 | 0.57 |

## 4. Acknowledgment

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## 5. Conclusion

In terms of shedding light on future studies; to obtain high haploidy frequency firstly donor plants should be grown under controlled conditions with intensive care. Keeping the number of anthers in culture as high as possible will increase the success. Refreshing the medium at certain stages of the culture, and the addition of activated charcoal are other important issues. Crossbreeding can be another solution to make unproductive genotypes productive. There is a need for new studies with the belief that making the embryo growth medium composition more effective to increase the success rate in the transformation of embryos into plants will increase the success.

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# Effect of Salt Doses on Biological Values in Durum Wheat

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**ABSTRACT**

This research was carried out to determine the response of some durum wheat cultivars to salt stress during the germination stage. In the study, in which 11 durum wheat varieties, which are widely produced in different regions of Turkey, were used, 3 g $l^{-1}$ and 6 g $l^{-1}$ doses of NaCl were applied in addition to the distilled water application. In the research, germination rate, germination power, root length, shoot length, fresh and dry weight properties were investigated. The study was carried out according to the Factorial Experiment Design in Random Plots under laboratory conditions. Statistically significant differences were found between cultivars and salt doses, except for fresh and dry weight, in terms of all traits examined. Additionally, variety x salt dose interactions were found as important in terms of other characteristics except for dry weight. The highest germination rate, germination power and dry weight were determined in Altıntaş-95, highest root length in Eminbey and highest fresh weight Yelken varieties. Except for and dry weight, other properties were significantly reduced with increasing salt dose.

## 1. Introduction

Wheat is the plant with the largest cultivation area among the cultivated plants grown for nutritional purposes in the world. It is used as a raw material for foods with high nutritional value such as durum wheat, bulgur and pasta among wheat species, cheap and widely used. In Turkey, which is an important durum wheat producer with Southeastern Anatolia and Central Anatolia regions, durum wheat production has reached approximately 3.15 million tons (Anonymous, 2020).

It is known that salinity is one of the most important abiotic stress factors reducing productivity in agricultural areas, and high salt concentration has a negative effect on seed germination and seedling formation (Fowler, 1991). Plants can easily absorb the soluble salt in the soil. Salt compounds entering the body of the plant show negative effects when they exceed a certain density. With the increase of salt concentration in the soil, it becomes difficult for the plant to take water from the soil, the structure of the soil deteriorates, and plant growth slows down or even stops (Kanber et al., 1992; Güngör and Erözel, 1994).

The negative effect of salinity is seen in more than 20% of agricultural areas in the world (Hafeez et al., 2021). In addition, the rehabilitation of saline areas is very expensive and it cannot be expected to be a permanent solution unless the factors causing salinity are eliminated. For this reason, the determination of salt-resistant varieties has an economic importance in terms of growing plants in these areas. In terms of salt tolerance, there are differences between families, genera and species as well as among varieties belonging to the same species (Kızılgeçi and Yıldırım, 2014).

Plants are more sensitive to salt in the early stages of their development than in other stages of development (Budaklı Çarpıcı and Doğan, 2015). For this reason, it is appropriate to carry out studies in which tolerance to salinity is determined at early developmental stages. The amount of salt present in the environment has a significant effect on the germination, healthy emergence and survival of the seed (Baldwin et al., 1996). Begum et al. (1992) reported that It is a fast and effective technique for determining salt-tolerant wheat varieties, applying salt to seeds during germination and early seedling development.

The high salt levels in the soil and the quality of the irrigation water used are among the factors of concern for future agriculture. Therefore, it is necessary to develop effective strategies to increase yields through salt tolerance (Salim and Raza 2020). The aim of this study is to determine the salt stress tolerance of some durum wheat cultivars grown in different regions of Turkey and to shed light on the studies on salt tolerance.

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## 2. Material and Method

In the research, 11 durum wheat varieties, which are widely produced in different regions of Turkey, were used. Seeds of the cultivars were produced in Konya ecological conditions during the 2020-2021 cultivation period. The research was carried out in the laboratory of the Department of Field Crops, Faculty of Agriculture, Selcuk University.

NaCl form, which is the most abundant in the soil, accumulates in the soil and affects the cultivated plants the most, was used as salt (Munns and Termaat, 1986). Accordingly, in which distilled water was used as a control, two different NaCl doses, 3 and 6 g $l^{-1}$, were applied to the seeds. Seeds were left to germinate in dark conditions at 24±1°C in the climate chamber. Before germination, the seeds were subjected to surface sterilization with 1% hypochlorite solution. The seeds were first kept in a solution containing hypochlorite (5% commercial bleach) for 15 minutes and then rinsed three times with sterile distilled water. 5 ml of each application was added to petri dishes with filter paper. 15 seeds were placed in petri dishes and covered with a second filter paper, 3 ml more was added from each application. The data on the examined features were obtained by measuring and counting on the 4th and 8th days in accordance with the ISTA criteria. Seeds exceeding 2 mm in rootlet length were considered as germinated and counted (Fuller et al., 2012). The "germination rate" was determined by counting the seeds germinated on the 4th day, and "germination power", "root length", "shoot length", "fresh weight" and "dry weight" were determined by counting and measurements made on the 8th day. While determining these characteristics, 10 seedlings randomly selected from each petri dish were used. Dry weight was determined by drying fresh shoots at 70°C for 24 hours (Atak et al., 2006; Saboora et al., 2006).

The data obtained from the experiment were subjected to statistical analysis using the JUMP-13 package program in accordance with the Factorial Experiment Design in Random Plots, and the mean values that were significant in the F test were divided into groups with the Student-t test.

## 3. Results and Discussion

The variance analysis results regarding the germination rate, germination power, root length, shoot length, fresh weight and dry weight characteristics of the wheat varieties used in the present research are given in Table 1.

Table 1
Variance analysis results of traits of durum wheat varieties examined at different salt doses

| | | F Value | | | | | |
|---|---|---|---|---|---|---|---|
| SOV | DF | Germination Rate | Germination Power | Root Length | Shoot Length | Fresh Weight | Dry Weight |
| Variety | 10 | 7.51** | 6.47** | 11.08** | 8.10** | 8.00** | 3.10* |
| Salt | 2 | \|218.96** | 115.78** | 161.43** | 288.02** | 1.92 | 0.73 |
| Variety x Salt | 20 | 4.99** | 3.84** | 7.33** | 3.84** | 4.57** | 1.25 |
| Error | 64 | - | - | - | - | - | - |
| Total | 98 | - | - | - | - | - | - |

*Germination Rate and Power*

According to the obtained results, statistically significant differences at the level of 1% were found between varieties and salt doses in terms of germination rate and germination power. In addition, the variety x salt interaction was found to be significant at the 1% level (Table 1).

The highest germination rate and power were determined in Altıntaş-95 variety. This was followed by Eminbey and Ç-1252 varieties, respectively. The lowest germination rate and power were determined in Svevo and Yelken cultivars (Table 2 and Table 3). The difference between the cultivars showing the highest and lowest germination rate and power was 19.3% and 24.8%, respectively. According to the findings of this study, the germination power values of the cultivars were largely parallel to the germination rate values. In terms of both characteristics, the cultivars in the first place and the cultivars in the last place were the same. In addition, in the multiple comparison test, groups were largely similar in terms of both characteristics. These differences between cultivars under laboratory conditions where all conditions are equal can be explained by the difference in salt sensitivity of genotypes.

While the highest germination rate and power values in all cultivars used were determined in the control application, significant decreases occurred in both traits as the salt doses increased (Table2 and Table 3). As the mean values of the cultivars, the germination rate in the control was 87.6% and the germination power was 94.5%, while the related characteristics were determined as 75.3% and 80.7% at 3 g $l^{-1}$ salt dose, 54.0% and 65.0% at 6 g $l^{-1}$ salt dose, respectively. According to these results, it can be said that increasing salt doses negatively affect embryo growth. Benlioğlu and Özkan (2015) state that this may be due to the decrease in the efficiency of water in salty environments, as well as the decrease in the transport of water and storage foodstuffs.

A previous study of Ekmekçi et al. (2005) stated that the decrease in germination rate at increasing salt levels is due to the toxicity of Na+ and Cl- ions, as well as the increasing osmotic pressure preventing the seed from taking up the water required for germination. Decreased germination rate and power at high salt doses may also be associated with higher cell membrane damage (Alamri et al., 2020). It has also been found in other studies that as the salt doses increase, the germination

rate and germination power decrease (Huang and Redmann 1995; Pancholi et al., 2001; Prazak, 2001; Şenay et al., 2005; Kara et al., 2011; Benlioğlu and Özkan 2015).

Table 2
Mean values for germination rate of durum wheat varieties at different NaCl doses and multiple comparison results

| Germination Rate (%) | | | | |
|---|---|---|---|---|
| Variety / Salt Dose | 0 | 3 g $l^{-1}$ | 6 g $l^{-1}$ | Mean |
| Altıntaş-95 | 95.5 a | 82.2 cde | 69.9 fgh | 82.6 a |
| Ç-1252 | 86.6 a-d | 82.2 cde | 57.8 ıj | 75.5 bc |
| Dumlupınar | 83.3 b-e | 64.4 hı | 56.6 ıj | 68.1 de |
| Eminbey | 93.3 ab | 91.1 abc | 66.6 ghı | 81.4 ab |
| Kunduru-1149 | 86.6 a-d | 91.1 abc | 39.9 l | 72.5 cd |
| Kızıltan-91 | 91.1 abc | 84.4 b-e | 44.4 kl | 73.3 cd |
| Mirzabey-2000 | 82.2 cde | 80.0 def | 43.3 kl | 68.5 de |
| Soylu | 88.9 a-d | 75.5 efg | 53.3 jk | 72.6 cd |
| Svevo | 83.3 b-e | 62.2 hıj | 44.4 kl | 63.3 e |
| Türköz | 91.1 abc | 68.9 gh | 57.7 ıj | 72.5 cd |
| Yelken | 82.2 cde | 53.3 jk | 60.0 hıj | 65.1 e |
| Mean | 87.6 a | 75.3 b | 54.0 c | |

Table 3
Mean values for germination power of durum wheat cultivars at different NaCl doses and multiple comparison results

| Germination Power (%) | | | | |
|---|---|---|---|---|
| Variety / Salt Dose | 0 | 3 g $l^{-1}$ | 6 g $l^{-1}$ | Mean |
| Altıntaş-95 | 97.8 ab | 93.3 a-d | 93.3 a-d | 91.4 a |
| Ç-1252 | 93.3 a-d | 86.6 b-f | 83.3 c-f | 81.4 bc |
| Dumlupınar | 93.3 a-d | 66.6 g-j | 75.5 f-ı | 78.5 bcd |
| Eminbey | 100.0 a | 88.8 b-f | 68.8 g-j | 85.9 ab |
| Kunduru-1149 | 95.5 abc | 91.1 a-d | 56.6 jkl | 81.1 bc |
| Kızıltan-91 | 95.5 abc | 86.6 b-f | 48.9 kl | 77.0 cd |
| Mirzabey-2000 | 97.8 ab | 88.8 a-e | 76.6 e-h | 84.0 bc |
| Soylu | 97.8 ab | 82.2 def | 57.7 jkl | 79.2 bcd |
| Svevo | 91.1 a-d | 62.2 j | 46.6 l | 66.6 e |
| Türköz | 95.5 abc | 77.7 efg | 76.6 e-h | 83.3 bc |
| Yelken | 93.3 a-d | 63.3 ıj | 60.0 jk | 72.2 de |
| Mean | 94.5 a | 80.7 b | 65.0 c | |

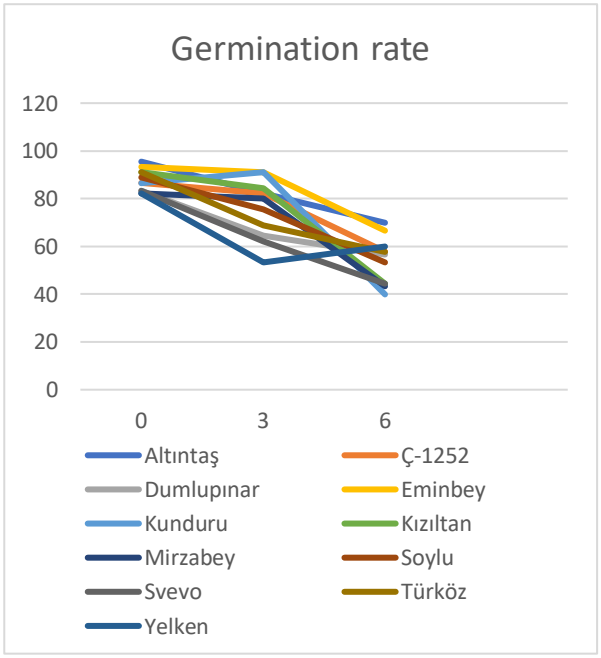


Figure 1
Interaction (variety x salt) graph of germination rate values of durum wheat varieties

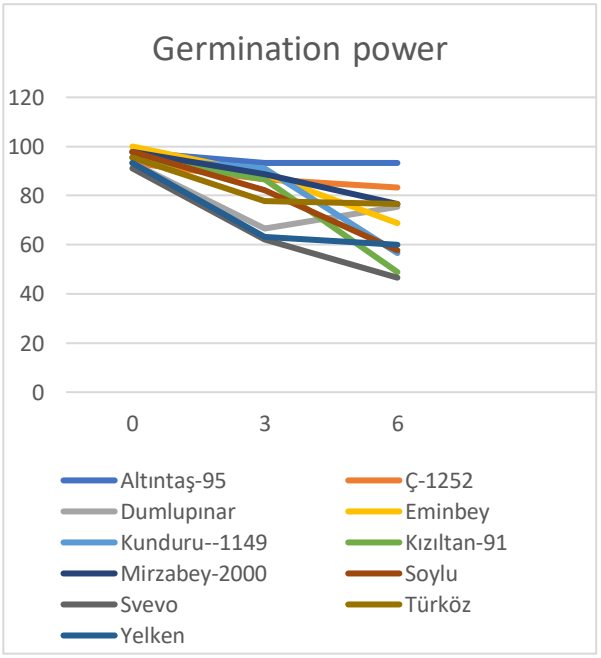


Figure 2
Interaction graph of germination power values of durum wheat varieties (variety x salt)

Present research showed that, the variety x salt interaction was found to be important in terms of germination rate and power. This is due to the different responses of cultivars to different salt doses. As a matter of fact, while the germination rate values of Kunduru-1149 cultivar were 86.6% in the control, it increased to 91.1% with an increase of 4.5% at the 3 g $l^{-1}$ salt dose and decreased to 39.9% at 6 g $l^{-1}$ dose. On the other hand, while the germination rate in Yelken variety was 82.2% in the control application, it decreased to 53.3% with a 28.9% decrease at 3 g $l^{-1}$ salt dose, and increased to 60.0% with an increase of 6.7% at 6 g $l^{-1}$ salt dose (Figure 1). Except for Kunduru-1149 and Yelken, the highest germination rate was determined in the control application, the germination rate values decreased regularly depending on the increasing salt dose, and the lowest values were determined at the highest salt dose.

In eight cultivars except Altıntaş-95, Dumlupınar and Türköz, the highest germination power values were obtained from the control application, and the germination power decreased significantly depending on the increasing salt dose (Figure 2). On the other hand, while the highest values were obtained from control in Altıntaş-95 and Türköz cultivars, germination power remained constant in both cultivars at 3 and 6 g $l^{-1}$ salt doses; In the Dumlupınar variety, the germination power, which was 66.6% at 3 g $l^{-1}$, increased to 75.5% at 6 g $l^{-1}$ salt dose. The results indicated that, the different response of cultivars to salt doses in terms of germination rate and germination power can be explained by the change in physiological characteristics of the cultivars depending on their genetic structures.

*Root and Shoot Length*

According to the results, statistically significant differences at the level of 1% were found between varieties and salt doses in terms of root and shoot length. In addition, the variety x salt interaction was found to be significant at the 1% level (Table 1).

The highest root length was determined in Eminbey variety, followed by Kunduru-1149, Kızıltan-91 and Altıntaş-95 varieties. The lowest root length was determined in Mirzabey-2000 and Türköz cultivars, respectively (Table 4). Additionally, the shoot length values of the cultivars were generally lower than the root length values. The highest shoot length was determined in Ç-1252 cultivar, followed by Dumlupınar cultivar, the lowest shoot length was determined in Kunduru-1149 and Svevo cultivars (Table 5).

Considering that all conditions are equal, the different performances of the cultivars in terms of root and shoot length can be explained by the change in the physiological characteristics of the cultivars depending on the genetic structure.

Table 4
Mean values for root length of durum wheat cultivars at different NaCl doses and multiple comparison test results

| | Root Length (cm) | | | |
|---|---|---|---|---|
| Variety / Salt Dose | 0 | 3 g $l^{-1}$ | 6 g $l^{-1}$ | Mean |
| Altıntaş-95 | 12.5 bcd | 8.9 ı-m | 7.0 m-p | 9.4 a |
| Ç-1252 | 8.2 j-n | 12.0 b-e | 7.2 m-p | 9.1 ab |
| Dumlupınar | 11.6 c-f | 6.8 nop | 9.2 h-l | 9.2 ab |
| Eminbey | 16.0 a | 7.3 l-p | 6.8 nop | 10.0 a |
| Kunduru-1149 | 12.7 bcd | 10.3 e-ı | 5.8 pq | 9.6 a |
| Kızıltan-91 | 13.9 b | 9.5 g-k | 6.3 nop | 9.9 a |
| Mirzabey-2000 | 6.1 opq | 7.5 k-p | 3.5 r | 5.7 c |
| Soylu | 13.6 bc | 8.2 j-n | 6.5 nop | 9.4 ab |
| Svevo | 11.2 d-g | 9.7 f-j | 6.4 nop | 9.1 ab |
| Türköz | 10.5 e-ı | 5.8 pq | 4.3 qr | 6.8 c |
| Yelken | 11.2 d-h | 8.0 j-o | 5.8 pq | 8.3 b |
| Mean | 11.6 a | 8.5 b | 6.2 c | |

Table 5
Mean values for shoot length of durum wheat cultivars at different NaCl doses and multiple comparison test results

| | Shoot Length (cm) | | | |
|---|---|---|---|---|
| Variety / Salt Dose | 0 | 3 g $l^{-1}$ | 6 g $l^{-1}$ | Mean |
| Altıntaş-95 | 8.2 bc | 6.6 d-g | 4.4 h-k | 6.4 de |
| Ç-1252 | 9.4 ab | 9.4 ab | 5.6 ghı | 8.1 a |
| Dumlupınar | 9.4 ab | 7.6 cde | 5.8 fgh | 7.6 ab |
| Eminbey | 10.4 a | 4.0 jkl | 3.7 klm | 6.0 ef |
| Kunduru-1149 | 8.0 bcd | 5.5 g-j | 2.5 lm | 5.3 f |
| Kızıltan-91 | 10.0 a | 7.9 b-e | 3.5 klm | 7.1 bcd |
| Mirzabey-2000 | 10.5 a | 6.5 efg | 4.2 ıjk | 7.1 bcd |
| Soylu | 10.4 a | 6.4 efg | 3.2 klm | 6.6 cde |
| Svevo | 6.9 c-g | 6.4 efg | 2.2 m | 5.3 f |
| Türköz | 10.2 a | 7.2 c-f | 3.5 klm | 7.0 bcd |
| Yelken | 10.4 a | 7.7 cde | 4.0 jkl | 7.3 abc |
| Mean | 9.4 a | 6.9 b | 3.9 c | |

Considering the mean values of 11 cultivars used in the study, the highest root and shoot length values were determined in the control application, while significant decreases occurred in both characteristics as the salt doses increased. While the mean values of the cultivars were 11.6 cm root length and 9.4 cm shoot length in the control, the relevant characteristics were determined as 8.5 cm and 6.9 cm at 3 g $l^{-1}$ salt dose, 6.2 cm and 3.9 cm at 6 g $l^{-1}$ salt dose, respectively. These results show that increasing salt doses negatively affect root and shoot length. In many studies on the subject, it has been stated that root length is significantly affected by salt stress (Jamil et al., 2005; Dumlupınar et al., 2007; Jafarzadeh and Aliasgharzad 2007; Benlioğlu et al., 2015).

In salty conditions, the hormones in the plant are negatively affected, as a result, while the cytokinin hormone, which promotes cell division and shoot development, decreases; On the other hand, the amount of abscisic acid (ABA) increases, which prevents early germination of seeds and ensures the closure of stomata (Güneş et al., 2007; Kumlay and Eryiğit 2011). Similarly, plant growth slows down due to Na toxicity in salty environments, and nutrient intake, especially calcium and potassium, decreases by causing both osmotic and ionic stresses (Zahra et al., 2018; Salim and Raza 2020).

Root development is one of the important indicators of salt resistance (Janmohammadi et al., 2012). Khan et al. (2003) stated that root length is an important parameter that can be used in the selection of salt-tolerant genotypes. During germination, if there is no salt barrier in water intake, rootlets develop normally, otherwise, rootlet development decreases due to salt stress (Oyiga et al., 2016).

According to the results of the present research, it was determined that the shoot lengths were shorter than the root lengths. Güneş et al. (2007) reported that the shoot length was more affected by the root length at increasing salt doses, which may be related to the change in the water status of the leaves while Salim and Raza (2020) reported that, the decrease in the water content of the leaves negatively affects photosynthetic activity and protein synthesis. The fact that shoot growth is more affected by root growth in saline environments can also be considered as a result of the effort to reduce the water requirement of the plant. Oyiga et al. (2016) stated that, in salty environments, a lower nutrient uptake occurs and the contribution of carbohydrates to young leaves is reduced.

Results of the present research revelaed that, it was determined that root and shoot length also changed significantly depending on the variety and salt concentration (Table 1). As a matter of fact, while the root length of Ç-1252 cultivar was 8.2 cm in the control, it increased to 12.0 cm with an increase of approximately 50% at a salt dose of 3 g $l^{-1}$, and decreased by approximately 41% at 6 g $l^{-1}$ dose Similarly, while Mirzabey-2000 cultivar had a root length of 6.1 cm in salt-free environment, the root length increased to 7.5 cm at 3 g $l^{-1}$ salt dose, and decreased to 3.5 cm with a decrease of more than 100% at 6 g $l^{-1}$ dose. While the root length was 11.6 cm in the control application of Dumlupınar cultivar, it decreased to 6.2 cm at 3 g $l^{-1}$ salt dose, and increased by 35% at 6 g $l^{-1}$ to 9.2 cm. On the other hand, in eight cultivars other than these three, the highest values were obtained in the control and root lengths decreased significantly depending on the increasing salt dose (Figure 3).

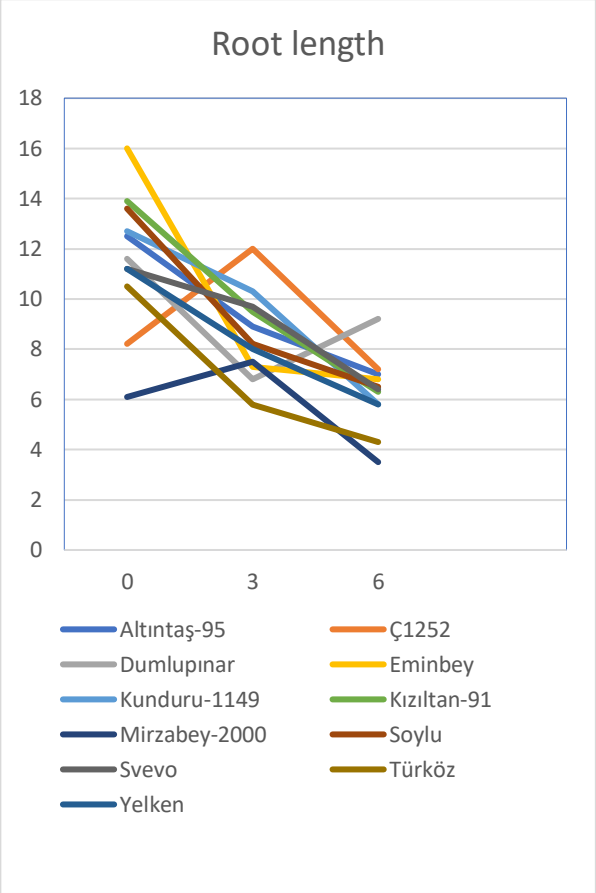


Figure 3
Interaction graph of root length values of durum wheat cultivars (variety x salt)

On the other hand, Ç-1252 and Eminbey cultivars reacted differently to increasing salt doses in terms of shoot length than other cultivars. For example, while shoot length was constant (9.4 cm) in control and 3 g $l^{-1}$ salt dose in Ç-1252 variety, it was found close to each other (4.0 and 3.7 cm, respectively) in Eminbey variety at 3 g $l^{-1}$ and 6 g $l^{-1}$ doses. In the other nine cultivars, shoot length was the longest in the control, while shoot lengths decreased significantly depending on the increasing salt dose (Figure 4). The difference in root and shoot lengths of genotypes according to salt concentration can be explained by the change in their physiological characteristics depending on the genetic structure of the cultivars.

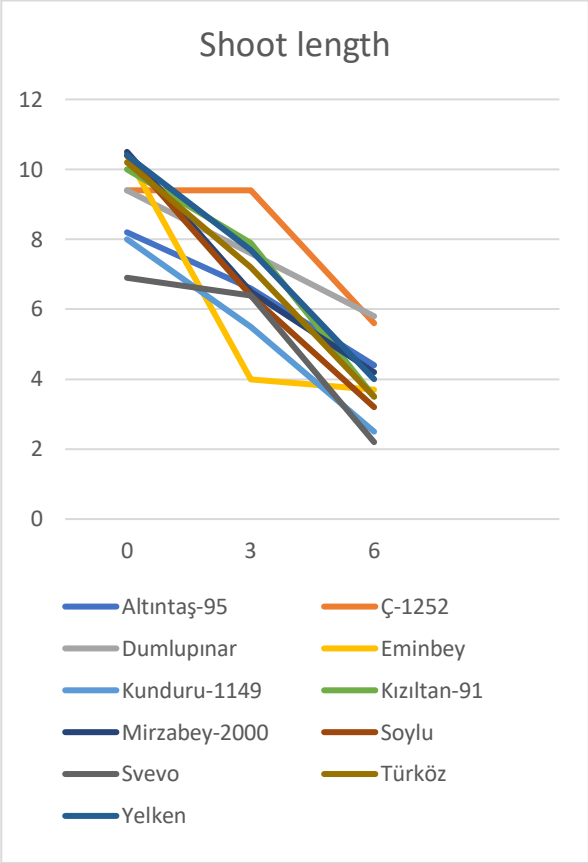


Figure 4
Interaction (variety x salt) graph of shoot length of durum wheat cultivars

*Fresh Weight and Dry Weight*

Analysis of variance revealed that, significant differences were determined between the varieties in terms of fresh weight at the level of 1% and in terms of dry weight at the level of 5%. In addition, the variety x salt interaction in terms of fresh weight was found to be significant at the 1% level (Table 1).

In the present research, the highest fresh weight was found in Yelken variety with 1.4 g, and the highest dry weight was determined in Altıntaş-95 variety with 0.60 g. The lowest fresh weight was determined in Dumlupınar, Soylu and Svevo, and the lowest dry weight was determined in Mirzabey-2000 and Svevo varieties (Table 6 and Table 7). In terms of dry weight, except Altıntaş-95 variety, the varieties in the first row and the varieties in the last row were found to be approximately the same in terms of both characteristics. These differences between varieties under laboratory conditions where all conditions are equal can be explained by the difference in salt sensitivity of genotypes.

Table 6
Mean values for fresh weight (g) of durum wheat varieties at different NaCl doses and multiple comparison test results

| | Fresh Weight (g) | | | |
|---|---|---|---|---|
| Variety / Salt Dose | 0 | 3 g $l^{-1}$ | 6 g $l^{-1}$ | Mean |
| Altıntaş-95 | 1.2 b-ı | 1.3 a-f | 0.9 ı-m | 1.1 bcd |
| Ç-1252 | 0.8 j-n | 1.5 abc | 1.4 a-e | 1.3 abc |
| Dumlupınar | 0.6 l-o | 0.5 no | 1.3 a-g | 0.8 e |
| Eminbey | 1.6 a | 1.4 a-f | 0.9 g-m | 1.3 abc |
| Kunduru-1149 | 1.2 b-ı | 1.3 a-f | 0.6 l-o | 0.9 de |
| Kızıltan-91 | 1.0 f-l | 1.4 a-f | 1.1 d-k | 1.2 bc |
| Mirzabey-2000 | 0.8 k-o | 1.2 b-j | 1.2 a-ı | 1.1 cd |
| Soylu | 0.9 g-m | 0.6 mno | 1.1 e-k | 0.8 e |
| Svevo | 0.4 o | 1.1 c-k | 0.9 h-m | 0.8 e |
| Türköz | 1.4 a-e | 1.3 a-g | 1.2 a-h | 1.3 ab |
| Yelken | 1.3 a-f | 1.5 a-d | 1.5 ab | 1.4 a |
| Mean | 1.0 | 1.1 | 1.1 | |

Table 7
Mean values for dry weight (g) of durum wheat varieties at different NaCl doses and multiple comparison test results

| | Dry Weight (g) | | | |
|---|---|---|---|---|
| Variety / Salt Dose | 0 | 3 g $l^{-1}$ | 6 g $l^{-1}$ | Mean |
| Altıntaş-95 | 0.54 | 0.64 | 0.62 | 0.60 a |
| Ç-1252 | 0.32 | 0.35 | 0.38 | 0.35 bcd |
| Dumlupınar | 0.35 | 0.30 | 0.27 | 0.30 d |
| Eminbey | 0.47 | 0.52 | 0.29 | 0.43 bcd |
| Kunduru-1149 | 0.26 | 0.32 | 0.32 | 0.30 d |
| Kızıltan-91 | 0.38 | 0.29 | 0.28 | 0.32 cd |
| Mirzabey-2000 | 0.27 | 0.29 | 0.28 | 0.28 d |
| Soylu | 0.32 | 0.35 | 0.38 | 0.35 bcd |
| Svevo | 0.30 | 0.26 | 0.28 | 0.28 d |
| Türköz | 0.36 | 0.46 | 0.35 | 0.39 bcd |
| Yelken | 0.48 | 0.45 | 0.53 | 0.48 ab |
| Mean | 0.41 | 0.38 | 0.36 | |

It was determined that there was no significant decrease in the fresh and dry weight values with the increase of the salt dose. Although the shoot and root length values decreased significantly due to the increasing salt dose, the lack of a significant change in the fresh and dry weight values may be due to the insufficient use of storage nutrients in the seeds during germination at high salt concentrations (Benlioğlu and Özkan 2015). Unlike the results which obtained from the present study, in some studies conducted on the subject, it was determined that the dry weights of the varieties showed higher values as the salt dose increased (Sultana et al., 2000; Benlioğlu and Özkan 2015).

Present research showed that, the responses of cultivars to salt concentrations in terms of fresh weight were also different. For example, while the fresh weight values of Dumlupınar, Eminbey, Soylu and Türköz cultivars decreased at different rates at a salt dose of 3 g $l^{-1}$ compared to the control, on the contrary, it increased at different rates in other cultivars (Figure 5).

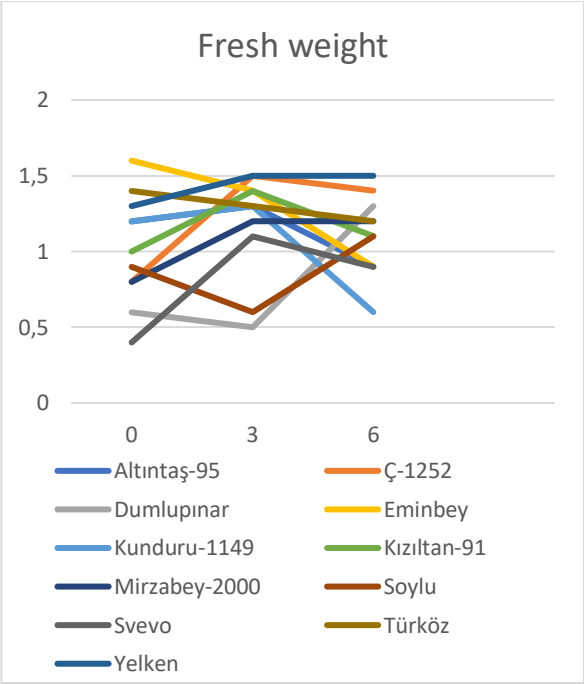


Figure 5
Interaction graph of fresh weight values of durum wheat varieties (variety x salt)

## 4. Conclusion

In this study, in which the responses of 11 durum wheat varieties, which are widely produced in Turkey, to different salt doses during the germination period were investigated, significant differences were found between the varieties in terms of all the examined characteristics. The highest germination rate and germination power were determined in Altıntaş-95 variety. This was followed by Eminbey and Ç-1252 varieties, respectively. The lowest germination rate and power were determined in Svevo and Yelken cultivars. In addition, the highest root length was determined in Eminbey variety, followed by Kunduru-1149, Kızıltan-91 and Altıntaş-95 varieties. The lowest root length was determined in Mirzabey-2000 and Türköz cultivars, respectively. Shoot length values were generally lower than root length values. The highest shoot length was determined in Ç-1252 cultivar, followed by Dumlupınar cultivar, the lowest shoot length was determined in Kunduru-1149 and Svevo cultivars. In addition to these findings, the highest fresh weight was found in Yelken variety with 1.4 g, and the highest dry weight was determined in Altıntaş-95 variety with 0.60 g. The lowest fresh weight was determined in Dumlupınar, Soylu and Svevo, and the lowest dry weight was determined in Mirzabey-2000 and Svevo varieties.

It was observed that with the increase of salt concentration, both the germination rate decreased and the germination was significantly delayed. Root and shoot lengths, which are important features in determining the salinity tolerance of genotypes, were found to decrease significantly with the increase in salt concentration. In the study, it was determined that the responses of the varieties to salt doses also changed in terms of other characteristics except dry weight.

According to the results obtained from the study, Altıntaş-95, Kunduru-1149, Mirzabey and Ç-1252 varieties can be recommended welded by germination power in conditions where salt concentration is high. It would be appropriate to propose a variety for salty soils after a study to be carried out to cover the germination and seedling periods.

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# Examination of Milk Samples, obtained from the Different Cattle breeds in the First Lactation, by Means of Discriminant Analysis

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**ABSTRACT**

By means of discriminant analysis, it can be identified which class the individuals (data) desired to be classified. In this study, it was aimed to identify that the milk samples belong to which breed, applying discriminant analysis to the milk samples taken from the cattle breeds (19 heads of Jersey, 53 heads of Holstein and 27 heads of Charolaise) in the first lactation. As a conclusion of the study, proper classification actualized in the rate, which can be considered quite high like 90.6%, according to the milk components (fat, protein, lactose, density, pH and conductivity) of Holstein Cattles. This rate actualized as 63.2% in Jersey and 25.9% in Charolaise. It was identified that the rate of general classification of non-linear analysis, used in discriminating Holstein, Jersey and Charolaise breeds from their milk components, was 67.7%.

## 1. Introduction

Milk is a porcelain white liquid, which has a specific and which is secreted in certain times in mammary glands of female mammals for them to be able to feed their young their kids, which contains all nutrients the kid has to receive until it reaches the position of being able to feed itself in the necessary rates (Çetiner, 2017). Cow milk is food that is rich in terms of mineral substances (especially calcium and phosphor). Calcium and phosphor needs of adults can be completely met by one liter of milk. Since calcium in milk is in an appropriate form, the milk is valued in the best way as a food (Demirci, 1981). In the group of milk and dairy products, the foods made of milk such as yoghurt, cheese and milk powder take place.

These foods are important resource of nutrient elements such as calcium, phosphor, B2 and B12 vitamins. Especially adult women, children and young people, those in all age groups have to consume the products in this group (Ünal and Besler, 2008). Milk does not have a constant composition and can differ according to the factors such as the species, breed age lactation period of animal, enterprise, region, calving season, feeding, animal health and the daily number and duration of milking. Milk yield mostly has importance for breeder and milk composition for milk industry. For example, the quality, efficiency and standard production of dairy products such as drinking milk, butter, yoghurt, cheese and powdered depend on the richness of composition of the raw milk coming to the processing plants of and the low variability of the composition (Yaylak et al., 2007). Fat content of milk differs according to the breeds. For example, Holstein contains fat of 3-3.5%; Brown Swiss, 3.8%; Jersey, 6.0%; Ayrshire, 4.5; Guernsey, 5.0% and Simmental 4.2 % (ESK, 2022).

That a total amount of dry substance in milk is more shows that milk is more suitable for the products such as cheese, milk powder, coagulated milk. The protein and fat content of the milk is extremely important to production of cheese. Knowing the factors changing composition of milk considerably helps to milk processing plants in planning their processes and forming marketing processes according to the coming raw milk (Yaylak et al., 2007). In no. 2019/64 official statement associated with classification of raw cow milk, published in Official Journal, numbered 31019, on the date of January 25, 2020, it was stated that the values of protein and fat would be considered in classification of raw cow milk (like in European Union Countries).

Discriminant analysis, taking into consideration, a number of features of individuals (independent variables), is a multi-variable statistical method, which is used in dividing the individuals into groups they belong to at optimal level with minimum fault, deciding which features (independent variables) are effective and stating that the individual is drawn from which group (Çiftçi, 2019). As a result of the analysis of the milk samples of

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[1] This study is a summary of the first author's master's thesis.

the cows of other breeds that are widely grown, a general correct classification rate can be determined and it will be advantageous to use the milk of unknown origin to determine which breed it belongs to.

There are many studies, in which discriminant analysis is used in the different areas of breeding. Kocabaş et al. (2003), in the studies they carried out and applied discriminant analysis by using physical properties of milk, stated that classification of unclear origin fleeces could be correctly made as Akkaraman or Anatolian Merino. In another study, again carried out on fleece, it was stated that Akkaraman or Anatolian Merino breeds could be properly classified in the rate of 81.9% (İlhan et al., 2009). Mahmood and Naeem (2011) made discriminant analysis for identifying the physical and chemical characteristics of water buffalo milk and demonstrated that discriminant analysis could be utilized in interpreting complex dataset. In related to this subject, Gençer (1996) examined the structural and behavioral features of ecotypes of honeybees in Central Anatolia and their various crossbreeds by means of discriminant analysis and, as result, showed that the right decisions could be made.

Although discriminant analysis is used in the different breeding areas, identifying the breeds from the milk compositions of Jersey, Charolaise and Holstein breeds could not be earlier met in the literature. Thanks to this, the current original study, adding the new information to the literature, is expected to fill a gap in this area.

In this study, utilizing discriminant analysis, it was aimed to classify the compositions (fat, protein, lactose, density, pH, conductivity) of milk samples of Jersey, Charolaise and Holstein breeds.

## 2. Material and Method

### *2.1. Materials*

The material of this study consists of the milk samples taken from 19 heads of Jersey, 53 heads of Holstein and 27 heads of Charolaise cows in the first lactation, bred in the private enterprises in the different provinces of Konya. The values of fat (%), lactose (%), density (kg/m$^3$), pH, conductivity (µS/cm) of the milk samples, taken by centrifugal tubes of 50 ml, from 99 heads of cow in the first lactation were identified by measuring once for each sample by Lactoscan MMC-30 milk analysis device.

### *2.1. Methods*

Discriminant analysis is examined under two main groups as linear and quadratic discriminant analysis. Linear discriminant analysis can be applied in case that sample data matrices, drawn from multi-variable populations exhibiting normal distribution, equal to intergroup variance covariance matrices ($S_1 = S_2 = \cdots = S_k$). If inter group variance covariance matrices are not equal, quadratic discriminant analysis is made. Whether or not intergroup variance covariance matrices are equal is controlled by means of *Box* M Test, developed by Box in 1949, is in the form of $Box\ M = MxC$ and shows Chi Square ($X^2$) distribution with $((k-1)/2)(p(p-1))$ freedom degree (Sangün, 2007).

$$BoxM = MxC \approx x^2_{\left[a,\left((k-1)/2\right)\left(p(p-1)\right)\right]}$$

Where, it is calculated by means of

$M = \sum_{i=1}^{k}(n_i - 1)\ln|S| - \sum_{i=1}^{k}(n_i - 1)\ln|S_i|$. $S$: is common variance covariance matrix calculated as follows:

$$S = S_{ortak} = \frac{\sum_{i=1}^{k}(n_i - 1)S_i}{\sum_{i=1}^{k} n_i - k}$$

$n_i$, denotes the number of observation in $i^{th}$feature

$k$, the number of group;

$|S|$, determinant of common variance covariance matrix;$S_i$ , covariance matrix belonging to $i^{th}$ group; and

$|S_i|$, determinant of variance covariance matrix belonging to $i^{th}$ group.

C is the number of observation in the groups and is obtained by means of the following formulas:

If, $n_1 \neq n_2 \neq \cdots \neq n_k$,

$$C = 1 - \frac{2p^2 + 3p - 1}{6(p+1)(k-1)}\left(\sum_{i=1}^{k} - \frac{1}{\sum_{i=1}^{k}(n_i - 1)}\right)$$

If, $n_1 = n_2 = \cdots = n_k = n$

$$C = 1 - \frac{(2p^2 + 3p - 1)(k+1)}{+(p+1)\big(k(n-1)\big)}$$

In the formula, $p$ denotes the number of features. In discriminant analysis, observation matrix X is obtained by combining observation matrices $X_1$ and $X_2$ containing observations regarding the totals of $\pi_1$ and $\pi_2$. From these data matrices, sample average vectors and covariance matrices are calculated as follows (Öztürk, 2006).

$$\bar{X}_1 = \frac{1}{n_1}\sum_{j=1}^{n_1} X_{1j}\,;\ S_1 = \frac{1}{n_1 - 1}\sum_{j=1}^{n_1}(X_{1j} - \bar{X}_1)(X_{1j} - \bar{X}_1)'$$

$$\bar{X}_2 = \frac{1}{n_2}\sum_{j=1}^{n_2} X_{2j}\,;\ S_2 = \frac{1}{n_2 - 1}\sum_{j=1}^{n_2}\big(X_{2j} - \bar{X}_2\big)(X_{2j} - \bar{X}_2)'$$

Accepting that the populations examined have the same covariance matrix (Σ), sample covariation matrices, union of $S_1$ an $S_2$ $S_p$ (pooled variance covariance matrix) is calculated as follows (Özdamar, 2004).

$$S_{pooled} = \frac{(n_1 - 1)S_1 + (n_2 - 1)S_2}{n_1 + n_2 - 2}$$

Common covariance matrix can also be calculated in the form of $\hat{\Sigma} = E(X - \bar{x}_i)(X - \bar{x}_i)$. By means of a separation function to maximize intergroup difference, it will be possible to separate the groups from each other. Therefore, a common separation function is formed. Classification function associated with each group can be written in the form of:

$$Y_i = b_{0i} + b_{1i}X_1 + b_{2i}X_2 + \cdots + b_{pi}X_p$$

i=1, 2 in the equation represents the number of group; $b_{i0}$ constant value $b_{ij}$(j = 1,2 ... p) canonic components and p is the number of variable. $\bar{X}_i$ as group average vector, constant value $b_{0i}$ and coefficients vector $b_{ij}$ can be calculated in the form of

$$b_{i0} = -\left(\frac{1}{2}\right)\bar{x}_i' S^{-1}\,\bar{x}_i$$

$b_{ij} = S^{-1}(\bar{X}_i)$ i = 1, 2…g, j=1, 2…p. Separation function for two groups is calculated as follows:

$$Y = b_0 + b_1X_1 + b_2X_2 + \cdots + b_pX_p$$

Canonic components $b_j$ (j=1, 2…p) are found by average difference factor $(X_1 - X_2)$ with the following equation.

$$b_i = S^{-1}(\bar{X}_i - \bar{X}_j)$$

If covariance matrices of the groups are not equal ($S_1 \neq S_2$), two groups of quadratic analysis are made and, instead of common variance (S), taking the differences of covariance ($S_1$-$S_2$) matrices of the groups, coefficients vector bj is calculated by the following equation for quadratic separation function (Kılıç et al., 2013).

$$b_j = (S_1^{-1} - S_2^{-2})(\bar{X}_1 - \bar{X}_2)$$

## 3. Results and Discussion

In Jersey, Charolaise and Holstein cattle, means and standard deviations belonging to milk components (fat, density, lactose, protein, pH and conductivity) are given in Table 1.

Table 1
The means and standard deviations of milk components

| Milk Components | Breeds | | |
|---|---|---|---|
| | Jersey $\bar{X} \pm S_{\bar{x}}$ | Charolaise $\bar{X} \pm S_{\bar{x}}$ | Holstein $\bar{X} \pm S_{\bar{x}}$ |
| Fat | 4.78±0.31$^{A}$ | 5.21±0.43$^{A}$ | 4.14±0.33$^{A}$ |
| Density | 42.60±1.13$^{A}$ | 36.12±1.12$^{B}$ | 35.43±0.54$^{B}$ |
| Lactose | 6.74±0.19$^{A}$ | 5.84±0.16$^{B}$ | 5.62±0.10$^{B}$ |
| Protein | 4.45±0.13$^{A}$ | 3.90±0.11$^{B}$ | 3.76±0.07$^{B}$ |
| pH | 7.12±0.02$^{A}$ | 6.98±0.04$^{B}$ | 6.94±0.02$^{B}$ |
| Conductivity | 4.59±0.11$^{A}$ | 4.39±0.09$^{A}$ | 4.50±0.04$^{A}$ |

A, B: p<0.01

In Table 1, in the samples belonging to Jersey breed, it is seen that the values belonging to the other milk components, other than fat, are higher than Charolaise and Holstein cows. According to milk components, unidirectional analysis was applied to cattle breeds and the features that turned out different were subjected to Duncan test, one of multiple comparison tests. As also seen in Table 1, the differences between cattle breeds in terms of density, lactose, protein and pH features were found statistically significant (p<0.01) and in terms of fat and conductivity, insignificant (p>0.05). In Table 2, covariance matrices belonging to milk components of cattle in Jersey, Charolaise and Holstein breeds are given. Correlation coefficient between milk components of cattle from Jersey, Charolaise and Holstein breeds are given in Table 3.

Table 2
Covariance Matrices Belonging to Milk Components

| Breeds | Milk Components | Fat | Density | Lactose | Protein | pH | Conductivity |
|---|---|---|---|---|---|---|---|
| Jersey | Fat | 1.818 | 3.953 | 0.802 | 0.538 | 0.066 | 0.153 |
| | Density | 3.953 | 24.424 | 4.016 | 2.695 | 0.183 | -0.220 |
| | Lactose | 0.802 | 4.016 | 0.680 | 0.456 | 0.035 | -0.012 |
| | Protein | 0.538 | 2.695 | 0.456 | 0.306 | 0.023 | -0.008 |
| | pH | 0.066 | 0.183 | 0.035 | 0.023 | 0.008 | 0.027 |
| | Conductivity | 0.153 | -0.220 | -0.012 | -0.008 | 0.027 | 0.216 |
| Charolaise | Fat | 4.998 | -2.701 | 0.271 | 0.189 | -0.128 | -0.430 |
| | Density | -2.701 | 33.727 | 4.493 | 2.992 | -0.063 | 0.173 |
| | Lactose | 0.271 | 4.493 | 0.691 | 0.461 | -0.027 | -0.020 |
| | Protein | 0.189 | 2.992 | 0.461 | 0.308 | -0.018 | -0.014 |
| | pH | -0.128 | -0.063 | -0.027 | -0.018 | 0.043 | 0.009 |
| | Conductivity | -0.430 | 0.173 | -0.020 | -0.014 | 0.009 | 0.219 |
| Holstein | Fat | 5.811 | 3.003 | 1.178 | 0.794 | -0.108 | -0.344 |
| | Density | 3.003 | 15.688 | 2.644 | 1.765 | -0.013 | -0.409 |
| | Lactose | 1.178 | 2.644 | 0.532 | 0.356 | -0.016 | -0.103 |
| | Protein | 0.794 | 1.765 | 0.356 | 0.238 | -0.011 | -0.069 |
| | pH | -0.108 | -0.013 | -0.016 | -0.011 | 0.014 | 0.012 |
| | Conductivity | -0.344 | -0.409 | -0.103 | -0.069 | 0.012 | 0.096 |

Table 3
Correlations between Milk Components

| Breeds | | Fat | Density | Lactose | Protein | pH |
|---|---|---|---|---|---|---|
| | Density | 0.593** | | | | |
| | Lactose | 0.721** | 0.985** | | | |
| Jersey | Protein | 0.721** | 0.985** | 1.000** | | |
| | pH | 0.538* | 0.404 | 0.460* | 0.461* | |
| | Conductivity | 0.244 | -0.096 | -0.032 | -0.032 | 0.628** |
| | Density | -0.208 | | | | |
| | Lactose | 0.146 | 0.931** | | | |
| Charolaise | Protein | 0.153 | 0.928** | 1.000** | | |
| | pH | -0.278 | -0.053 | -0.158 | -0.159 | |
| | Conductivity | -0.411* | 0.064 | -0.052 | -0.054 | 0.089 |
| | Density | 0.315* | | | | |
| | Lactose | 0.670** | 0.915** | | | |
| Holstein | Protein | 0.675** | 0.913** | 1.000** | | |
| | pH | -0.377** | -0.027 | -0.181 | -0.185 | |
| | Conductivity | -0.461** | -0.333* | -0.457** | -0.457** | 0.319* |
| | Density | 0.169 | | | | |
| | Lactose | 0.478** | 0.945** | | | |
| Overall | Protein | 0.482** | 0.943** | 1.000** | | |
| | pH | -0.182 | 0.230* | 0.143 | 0.141 | |
| | Conductivity | -0.325** | -0.039 | -0.132 | -0.133 | 0.260** |

*: p<0.05; **: p<0.01

As can be seen from Table 3, for overall milk samples, considerably high and statistically significant correlations (p<0.01) were identified between density and lactose (0.945), between density and protein (0.943) and between lactose and protein (1.000).

For checking whether or not the assumption that variance covariance matrices are homogeneous is provided, Box's M test is used (Sangün, 2007). As a result of the analysis made, it was identified that the value of Box's M was 486.551. According to this result, variance covariance matrices are not equal. As a result of this assumption, deciding to make quadratic analysis on the data, analysis was continued.

For identifying how much important the separation functions formed are, the values of canonic correlation, eigenvalue and Wilks Lambda statistics were referred to. In the analysis, Jersey, Charolaise and Holstein breeds were coded as dependent variables and milk components as independent variables, and quadratic discriminant analysis was made. The values showing importance control of separation functions are given in Table 4 and Table 5.

Table 4
The values of Eigenvalue Statistics

| Function | Eige value | Variance (%) | Cumulative (%) | Canonical Correlation Value and Square |
|---|---|---|---|---|
| 1 | 0.596 | 87.4 | 87.4 | 0.611 / 0.373 |
| 2 | 0.086 | 12.6 | 100 | 0.281 / 0.079 |

Table 5
The values of Wilks Lambda Statistics

| Function | Wilks Lambda | Chi-Square | DF | Sigma |
|---|---|---|---|---|
| 1 | 0.577 | 51.696 | 10 | 0.000 |
| 2 | 0.921 | 7.734 | 4 | 0.102 |

Depending on the magnitude of the statistical value of eigenvalue a large part of variance is accounted for by that function. In general, that eigenvalue is bigger than 0.40 is accepted as good (Cangül, 2006). According to this, a large part of the variance in dependent variable is accounted for by the first function, where eigenvalue is 0.596.

Canonic correlation measures the relationship between separation scores and groups and shows total variance explained (Altay and Yiğit, 2021). The square of this value expresses total variance, which separation function accounts for on the dependent variable. According to this, when the values in Table 4 are examined, it is seen that 1st function accounts for total variance on the dependent variable in the rate of 37.3% and, 2nd function, in the rate of 7.9%.

Wilks lambda statistics takes values between 0 and 1. Big values of Wilks Lambda expresses that group means are not different. The smaller the value of Wilks Lambda is, the more discriminating power of model increases (Cangül, 2006). The value of Wilks lambda expresses the rate of variance that cannot be explained between the groups. According to Table 5, depending on the value of Wilks lambda, the variance that cannot be explained for the 1st and 2nd function turned out 57.7% and 92.1%, respectively; and this expression reveals that the 1st function is more effective. The importance of Wilks Lambda expresses whether or not the functions

formed are not discriminated from each other. According to this, two separation functions formed according to the importance of Wilks Lambda taking place in Table 5 can significantly separate the groups from each other. In other words, the groups of 1st and 2nd separation functions formed can be significantly separated from each other ($p<0.01$).

The basis of discriminant analysis is to find a function to provide identification of main mass of the individual (Cangül, 2006). Separation functions used in discriminant analysis are formed by means the following formulas according to the coefficient values of canonic separation functions taking place in Table 6.

$$Y = b_0 + b_1X_1 + b_2X_2 + \cdots + b_pX_p$$

Where, Y denotes separation score; $h_0$, constant; b's, separation coefficients; X's, independent variables. As a result of discriminant analysis made, two pieces of separation functions were obtained. According to the coefficients of canonic separation function, the 1st and 2nd separation functions are as follows:

$$Y_1 = -38.320 - 0.006\ Fat + 0.049\ Density + 0.749\ Lactose + 4.371\ pH + 0.349\ Conductivity$$

$$Y_2 = -12.098 + 1.690\ Fat + 1.453\ Density - 10.564\ Lactose + 2.349\ pH - 0.771\ Conductivity$$

The values of canonic separation functions stated above are given in Table 6.

Table 6
The coefficients of canonic separation functions

| Function | Independent Variables | Coefficient of Function | Constant |
|---|---|---|---|
| 1 | Fat | -0.006 | -38.320 |
| | Density | 0.049 | |
| | Lactose | 0.749 | |
| | pH | 4.371 | |
| | Conductivity | 0.349 | |
| 2 | Fat | 1.690 | -12.098 |
| | Density | 1.453 | |
| | Lactose | -10.564 | |
| | pH | 2.349 | |
| | Conductivity | -0.771 | |

In discriminant analysis, the achievement of analysis is the real percentage of classification. With this expression, depending on the magnitude of real classification percentage, it is proved that analysis is extremely successful. By means of analysis, the falsely or correctly classified observation data according to the breeds and achievement percentage are given in Table 7.

Table 7
The results and achievement percentages according to discriminant analysis

| Predicted Group | Breeds | Number | | | Correct Classification Rate |
|---|---|---|---|---|---|
| | | Jersey | Charolaise | Holstein | |
| | Jersey | 12 | 1 | 1 | 63.2 |
| | Charolaise | 1 | 7 | 4 | 25.9 |
| | Holstein | 6 | 19 | 48 | 90.6 |
| Total | | 19 | 27 | 53 | |

According to Table 7, in terms of milk features, the breeds are divided into the correct classes in the rate of 67.7% ((12 + 7+ 48)/ 99 = 67.7%). While 12 from 19 Jersey breed cows took place in the correct class, 7 cows (1 Charolaise, 6 Holstein) took place in the wrong group. While 7 from 27 Charolaise breed cows were correctly classified, 20 of them were wrongly classified (1 Jersey 19 Holstein). While 48 from 53 Holstein cows were correctly classified, only 5 (1 Jersey, 4 Charolaise) of them were wrongly classified. In addition, analysis results were expressed as percentage, Jersey breed cows were correctly classified in the rate of 63.2% and wrongly, in the rate of 36.8%. While Charolaise breed cows were properly classified in the rate of 25.4% and wrongly in the rate of 74.1%, Holstein breed cows were correctly classified in the rate of 90.6% and wrongly in the rate of 9.4%. According to discriminant analysis, the distribution of group (breed) data are given in Figure 1.

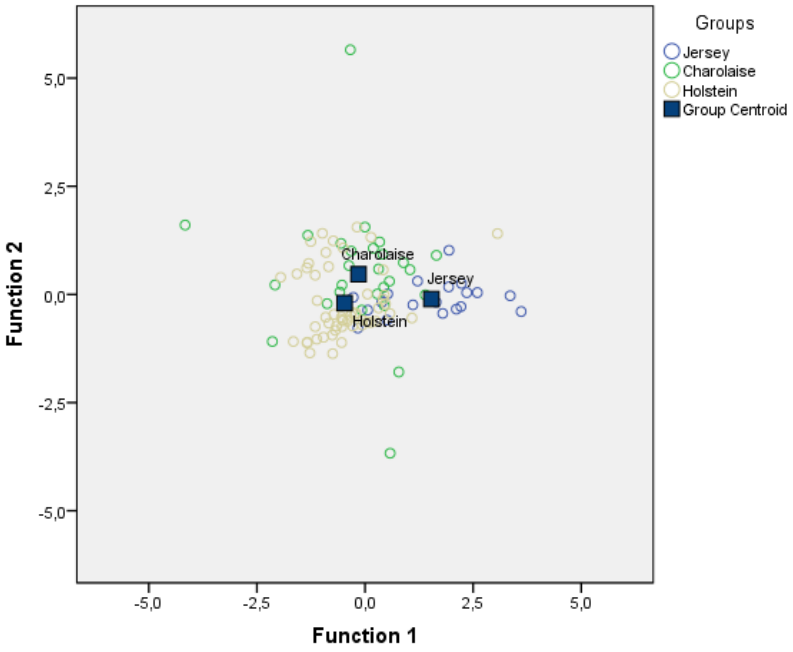


Figure 1
According to discriminant analysis, graphical view of the distributions of group data

As also seen from Figure 1, Holsteins formed a group and also Jerseys, a distinct group. Although Charolaise breed cows are divided as a distinct group, it is seen that some part of the cows (19 heads of Charolaise cow) takes place in Holstein, while one of them takes place in Jersey.

## 4. Conclusion and Suggestions

Discriminant analysis is a statistical technique, which enables researchers to study on the difference between 2 and more sample groups, in general, it utilizes some mathematical equations in grouping units. These equations, called separation functions are used to identify the common features of the groups in such way that it will enable to identify the most similar groups. Discriminant analysis is made to find separation functions enabling to discriminate the groups from each other, and, by means of these functions, to reveal separation variable that affects the separation the most and, by means of separation functions calculated, to identify that the newly observed unit will be included in which group in such a way that separation error will be minimum (Bayram, 2002).

As a result of the discriminant analysis made in this study, according to milk features (fat, protein, lactose, density, pH and conductivity) of Holstein cows, correct classification actualized in a rate that can be accepted as considerably high like 90.6%. This rate was 63.2% for Jerseys and 25.9% for Charolaise. It was identified that the rate of correct classification of nondirectional discriminant analysis, used in discriminating the milk features of Holstein, Jersey and Charolaise breeds, was 67.7%. Namely, in the milks, unknown to which breed, using the features such as fat, density, conductivity, that they belong to which breed can be correctly identified in the rate of 67.7%. However, it may be more accurate to determine a general correct classification rate as a result of taking milk samples from cows belonging to other breeds that are widely raised and examining them with separation analysis, and using milk of unknown origin to determine which breed it belongs.

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**Research Article**

# Inhibitory Effect of Oregano and Laurel Essential Oils and Their Main Components on Seed Germination of Some Weed and Crop Species

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**ABSTRACT**

The essential oils from oregano (*Origanum syriacum* L.) and laurel (*Laurus nobilis* L.), and their main components, namely**,** carvacrol, 1,8-cineole and α-pinene, were tested to determine their inhibitory effects on the seed germinations of three different weeds [redroot amaranth (*Amaranthus retroflexus* L.), wild licorice (*Glycyrrhiza glabra* L.), curled dock (*Rumex crispus* L.) and cutleaf ground-cherry (*Physalis angulata* L.)] and three crops [(wheat (*Triticum aestivum* L.), corn (*Zea mays* L.) and cotton (*Gossypium hirsitum* L.)]. Gas chromatography/mass spectroscopy (GC-MS) analysis showed that 1,8-cineole and carvacrol were the major components of laurel and oregano essential oils, respectively. An *in-vitro* bioassay seed germination test showed that oregano essential oil and carvacrol completely inhibited the germination of weeds at all the concentrations ranging from 1 to 5 µl/Petri dish, while seed germination of test weeds significantly decreased with increasing of the concentrations of laurel essential oil and its main components, 1,8-cineol and α-pinene ranging from 5 to 20 µl/Petri dish. Oregano essential oil and carvacrol were totally ineffective on cotton and corn germination (except for the concentration of 5 µl/Petri dish of cavracrol), whereas they had a strong inhibitory activity against wheat seeds. On the other hand, the laurel essential oil and its main component, 1,8-cineole, showed less selective action on test crop species. It could be concluded that volatile oil from *O. syriacum* and its main component, cavracrol, possessed a strong inhibitory effect on germination of the weeds and was totally selective action on some crops, and could be utilized as bioherbicide for future weed management programmes.

## 1. Introduction

Environmental constraints of crop production systems have stimulated interest in alternative weed management strategies. In fact, the continued use of synthetic herbicides may threaten sustainable agricultural production and has resulted in serious ecological and environmental problems, such as the increased incidence of resistance in weeds to important herbicides and increased environmental pollution and health hazards (Narwall 1999; Heap 1999). Therefore, there has, recently, been growing interest in research concerning the possible use of plant extracts as an alternative to synthetic herbicides (Dudai et al., 1993; 1999; Singh et al., 2005; Bozhuyuk, 2020; Karaman et al., 2021).

Allelopathy offers potential for selective biological weed management through the production and release of allelochemicals from the leaves, flowers, seeds, stems and roots of living or decomposing plant materials (Weston, 1996). Under appropriate conditions, allelochemicals may be released in quantities suppressive to developing weed seedlings (Wu et al., 2002). A variety of allelochemicals has been identified, including essential oils that inhibit seed germination and plant growth (Neori, 2000). Among natural plant products, volatile essential oils and their constituents have attracted much attention because of their phytotoxicity (also providing allelopathic property) and relatively quicker degradation in the environment (Muller, 1965; Dudai et al., 1999; Romagni et al., 2000; Tworkoski, 2002).

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Terpenoids, particularly monoterpenes and sesquiterpenes, are the main components of essential oils and are often responsible for their inhibitory activity. Among the many species of Lamiaceae family release phytotoxic monoterpenes that hinder the development of herbaceous species (Muller, 1966; Alsaadawi et al., 1985) among which the common ones are α- and β-pinene, camphene, limonene, α-phellandrene, ρ-cymene, 1,8-cineole, borneol, pulegone and camphor (Fisher, 1986). Allelopathic inhibition typically results from the combined action of a group of allelochemicals that interfere with several biochemical interactions among plants, including those mediated by soil microorganisms (Bozhuyuk, 2020; Yasar et al., 2021).

The flora of Turkey includes plant species that have been traditionally produced for centuries and used in folk medicine, some as spices and additives in perfumes. Many different species of local plants such as *Laurus nobilis* L. (Lauraceae), the laurel, and *Origanum syriacum* L. (Lamiaceae), rosemary, have a long history of use as medicinal plants and spices. The laurel is a perennial, flowering tree, which is commonly found in Mediterranean climate. *Origanum* (Lamiaceae) species are well known for their essential oils. Among them, thyme (*Thymus vulgaris* L.) is widely grown in different parts of the world for its essential oils that are used in perfumery and as flavouring agents besides possessing pesticidal properties (Langenheim, 1994; Isman, 2000). Morover, Angelini et al. (2003) reported that aqueous solution of essential oil from oregano and cavracrol had a strong inhibiting activity on the seeds of three different annual weeds (*Chenopodium album*, *Portulaca oleracea*, and *Echinochloa crus-galli*) and three crops (*Raphaus sativus*, *Capsicum annuum* and *Lactuca sativa*). Various studies have demonstrated inhibitory effect of various essential oils on seed germination of some weed species (Dudai et al., 1999; Onen et al., 2002; Angelini et al., 2003; Singh et al., 2003; Thompson et al., 2003). Various essential oils and their volatile constitutes as weed germination inhibitor against three different annual weeds (*Chenopodium album*, *Portulaca oleracea* and *Echinochloa crus-galli*) and three crops (*Raphanus sativus*, *Capsicum annuum* and *Lactuca sativa*) indicated that savory (*Satureja montana* L.) essential oil inhibited completely the germination of test weeds while concurrently displaying little effect on pepper (Angelini et al., 2003). However, very little has been done to explore the effect of essential oil from oregano and laurel, and their main components in vapor phase on the germination of the seeds of some weed species and crops studied here.

Objective of this study were: to identify chemical compositions of oregano and laurel essential oils, to evaluate *in vitro* the inhibitory activity of oregano and laurel essential oils and their main compounds (cavracrol, 1,8 cineole and α-pinene) in vapor phase on the seed germination of some weed and crop species, and to discuss their possible use as bio-herbicide for future weed management.

## 2. Materials and Methods

*Weed and Crop seeds*

Mature seeds of the weeds redroot amaranth (*Amaranthus retroflexus* L.), wild licorice (*Glycyrrhiza glabra* L.), curled dock (*Rumex crispus* L.) and cutleaf ground-cherry (*Physalis angulata* L.) were collected from parent plants in Karamanmaraş region in Turkey. Weed seeds were dried under the sun-light and then rubbed gently over a sieve to remove excess chaff, which, together with empty seeds, was removed with a seed blower. Dry seeds were stored at 10 ºC under relative humidty (RH) of 35% until germination testing began. Certified seeds with recommended germination and purity characteristics of cotton (*Gossypium hirsitum* L.), wheat (*Triticum aestivum* L.), and corn (*Zea mays* L.) were used kindly provided by Beyazaltın Seed Co.

*Plant materials and distillation procedure*

The plant materials of *O. syriacum* and *L. nobilis* were collected in highlands of Kahramanmaraş Province of Turkey during the spring of 2005. Raw materials for each sample were obtained from same area. The essential oil of oregano was obtained from their fresh leaves. The essential oils from the fresh leaves of *O. syriacum* and *L. nobilis* were extracted by steam distillation in stainless steel tank. After extraction, the essential oil was dried over anhydrous sodium sulphate, then were collected in sealed glass containers and were refrigerated in the dark at 4 ºC until their use. Cavracrol, 1,8-cineole and α-pinene were purchased from Aldrich.

*Gas chromatography-mass spectrometry procedure*

The percent content of components in the essential oils from oregano and laurel described above (11.5 mg) diluted in petroleum ether ($Et_2O$) (1 ml) was determined on a Finnigan-MAT 8200 Mass Spectrometer (low resolution) coupled with a Hewlett-Packard GC-5890II series GC and a SE-54 fused silica capillary column (30 m x 0.25 mm i.d.; 0.25 µm film thickness). One µl of the diluted oil was injected into the column. The GC oven temperature was kept at 60 ºC for 5 min and programmed to 260 ºC at a rate of 2 ºC $min^{-1}$ and then kept at 260 ºC. The injector temperature was 250 ºC. The amount of injection was 1 µl. The carrier gas (He) with a flow rate of 1.15 ml $min^{-1}$ was delivered at a constant pressure of 5 kg $cm^{-2}$. MS spectra were taken at EI ion source of 70 eV. Split ratio was 1:5. The components of the oil were identified by comparison of their mass spectra with that of internal (computer) library, NIST libraries, reference compounds and those described by Adams (1995). Identification of the essential oil was conducted by Gas Chromatography with flame ionization detector (GC-FID) on a Hewlett-Packard GC-5890II series GC. One µl oil sample was injected into the same column under the same GC conditions as described for Gas chromatography/mass spectroscopy (GC-MS) study. However, split ratio was 1:14.

*Weed and crop germination bioassay procedure*

Seeds of the weeds (*G. glabra*, *R. crispus* and *P. angulata)* and the crops (corn, wheat and cotton) were rinsed with distilled water and then shade-dried on the

filter paper in the laboratory at 25ºC for 7 days. These were then equidistantly placed in 9 cm diameter Petri dishes (10 seeds per Petri dish, six replicates per treatment) lined with two layers of moistened Whatman No. 1 filter paper wetted with 7 ml of distilled water. A piece of filter paper (3 cm diameter) stuck on the inner side of cover of Petri dishes was treated with 0, 1, 2, 3, 4 and 5 µl per Petri dishes of oregano essential oil and carvacrol, and 0, 5, 10, 15 and 20 µl per Petri dishes of laurel essential oil, 1,8-cineol and α-pinene. After closing the covers treated with oregano and laurel essential oils, carvacrol, 1,8-cineol and α-pinene, Petri dishes were sealed with paraffin film and placed in an illuminated growth chamber at 25±1ºC temperature and 65±5% R.H. in the darkness. After two weeks, the number of seeds that germinated (0.5 cm radicule length) was counted in each Petri dishes and then germination percentages of each treatment were calculated. Control treatments were kept without loading the essential oils, carvacrol, 1,8-cineole and α-pinene.

*Experimental design and data analysis*

A completly randomized design with six replicates adopted for the germination trials. Data were submitted to analysis of variance after arcsin transformation, and the means were separated using LSD test at $P \leq 0.05$ significant level (SAS, 1989).

## 3. Results and Discussion

*Chemical composition of essential oils of Origanum syriacum and Laurus nobilis*

Chemical compositions of essential oils from the leaves of oregano (*O. syriacum*) and laurel (*L. nobilis*) from Kahramanmaraş Province in Turkey are given in Table 1. The major components in the essential oil from the oregano were found to be carvacrol (73.47%), γ-Terpinene (2.50%), B-caryophyllene (2.29%), Borneol (1.75%) and E-Sabinene hydrate (0.80%). However, laurel essential oil essentially contained 1,8-cineole (54.71%), sabinene (9.19%), *α*-terpinyl acetate (6.95%), *α*-pinene (5.34%) and *B*-pinene (4.28%). Chemical analysis clearly indicated that carvacrol and 1,8-cineole were the main component of oregano and laurel essential oils respectively.

Table 1
Chemical composition of essential oils from oregano (*Origanum syriacum* L.) and laurel (*Laurus nobilis* L.)

| Components of *O. syriacum* | Component in vol. -% of components ± SD | Components of *L. nobilis* | Component in vol.-% of components±SD |
|---|---|---|---|
| Carvacrol | 73.47±0.15 | 1,8-cineole | 54.71±0.13 |
| γ-Terpinene | 2.50±0.09 | Sabinene | 9.19±0.09 |
| B-caryophyllene | 2.29±0.07 | *α*-terpinyl acetate | 6.95±0.01 |
| Borneol | 1.75±0.04 | *α*-pinene | 5.34±0.12 |
| E-sabinene hydrate | 0.80±0.02 | *B*-pinene | 4.28±0.005 |
| Terpinene-4-ol | 0.77±0.01 | *p*-cymene | 3.04±0.02 |
| Thymol | 0.70±0.01 | Terpinen-4-ol | 2.60±0.02 |
| 1,8-Cineole | 0.34±0.08 | *α*-terpineol | 1.90±0.03 |
| | | γ-terpinene | 0.90±0.04 |

*Germination Inhibition of Oregano Essential Oil and Carvacrol*

Data from the germination trials in weed seeds treated with oregano essential oil and carvacrol at different concentrations are shown in Table 2. Oregano essential oil and carvacrol indicated strong toxicity to seeds of all the weed species tested. Thus, essential oil completely inhibited germination in three weed species (*G. glabra*, *R. crispus* and *P. angulata*) at all the concentrations. For species *A. retroflexus*, while very low germination was obtained at the lowest concentration (1 µl/Petri dish), rest of three concentration of oregano essential oil resulted in completely inhibited germination. On the other hand, carvacrol completely inhibited germination in all weed species at all the concentrations. Germination percentage for all treatments clearly differed from the controls.

Table 2
Effect of different concentrations of oregano essential oil and carvacrol on the seed germination of tested weeds

| Treatments | Treatment rate (µl/Petri dish) | Germination rate (%) ± Standard Error* | | | |
|---|---|---|---|---|---|
| | | *Amaranthus retroflexus* | *Glcycrrhiza glabra* | *Rumex crispus* | *Physalis angulata* |
| *Oregano* essential oil | 1 | 3.3±1.7 B a | 0±0 B a | 0±0 B a | 0±0 B a |
| | 2 | 0±0 C a | 0±0 B a | 0±0 B a | 0±0 B a |
| | 3 | 0±0 C a | 0±0 B a | 0±0 B a | 0±0 B a |
| | 4 | 0±0 C a | 0±0 B a | 0±0 B a | 0±0 B a |
| | 5 | 0±0 C a | 0±0B a | 0±0 B a | 0±0B a |
| Carvacrol | 1 | 0±0 B a | 0±0B a | 0±0 B a | 0±0 B a |
| | 2 | 0±0 B a | 0±0 B a | 0±0 B a | 0±0 B a |
| | 3 | 0±0 B a | 0±0 B a | 0±0 B a | 0±0 B a |
| | 4 | 0±0 B a | 0±0 B a | 0±0 B a | 0±0 B a |
| | 5 | 0±0 B a | 0±0 B a | 0±0 B a | 0±0 B a |
| Control | 0 | 78.3 ±3.3 A a | 73.3±6.7 A a | 63.3 ±3.3 A b | 80 ±5.8 A a |

*Satistical analyses were carried out on arcsin-transformed data and results were extrapolated to original data. Two-way ANOVA was applied for data analysis. Means within a column with the same upper-case letter and a row with the same lower-case letter are not significantly different at 1% level by LSD test.

Data from the germination trials in seeds of crop species treated with oregano essential oil and cavracrol at two concentrations are shown in Table 3. Crop species responded differently to both oregano essential oil and carvacrol in terms of seed germination. Both oregano essential oil and carvacrol had no effect on the germination of cotton seeds, giving a hundred percent of germination at all concentration similar to control. Whereas, except for the lowest concentration (1µl/Petri dish), they completely inhibited germination in wheat seeds. In corn seeds, while a hundred percent of germination was obtained at the lowest concentration (1 µl/Petri dishes) of both oregano essential oil and carvacrol, the germination was significantly reduced in response to only carvacrol at the highest concentration (5 µl/Petri dish) compared to control.

Table 3
Effect of different concentrations of oregano essential oil and carvacrol on the seed germination of tested crop species

| Treatments | Treatment rate (µl/Petri dish) | Germination rate (%)±Standard Error * | | |
|---|---|---|---|---|
| | | Wheat | Corn | Cotton |
| *Oregano* essential oil | 1 | 100±0 A a | 100±0 A a | 100±0 A a |
| | 5 | 0±0 B b | 93.3±6.6 A a | 100±0 A a |
| Carvacrol | 1 | 0±0 B b | 100±0 A a | 100±0 A a |
| | 5 | 0±0 B c | 56.7±3.3 B b | 100±0 A a |
| Control | 0 | 100±0 A a | 100±0 A a | 100±0 A a |

*Satistical analyses were carried out on arcsin-transformed data and results were extrapolated to original data. Two-way ANOVA was applied for data analysis. Means within a column with the same upper-case letter and a row with the same lower-case letter are not significantly different at 1% level by LSD test.

*Germination Inhibition of Laurel Essential Oil, 1,8-Cineole and α-Pinene*

The effect of different concentration of laurel essential oil and its main components, 1,8-cineole and α-pinene, on the seed germination of tested weeds is shown in Table 4. Laurel essential oil and its main components, 1,8-cineole and α-pinene had a significant effect on seed germination of test weed species ($P$<0.01). Seed germination of test weeds was significantly reduced by an increase in the concentrations of laurel essential oil and its main components, 1,8-cineole and α-pinene ranging from 5 to 20 µl/Petri dish. Laurel essential oil completely inhibited germination in the three weed species (*A. retroflexus*, *G. glabra* and *P. angulata*) at higher concentrations of 15 and 20 µl/Petri dish, while *R. crispus* had very low percentages of seed germination (10-13.3%). On the other hand, at low concentration of 5 µl/Petri dish it caused a significant decrease in germination percentage, but not completely inhibited seed germination in all the test weed species. 1,8-cineole at all the treatments rates completely inhibited germination in only one weed species, *G. glabra*. This component at the lowest concentration (5 µl/Petri dishes), however, led to a low inhibition of seed germination in *A. retroflexus*, *R. crispus* and *P. angulata*, while its higher concentrations (15 and 20 µl/Petri dish) produced either complete or very low inhibition in seed germination (except for *P. angulata* at 15 µl/Petri dish). The other main component of laurel essential oil, α-pinene, led to significant increase in inhibiting seed germination of test weed species with increased concentration of α-pinene from 5 to 20 µl/Petri dish. At low concentration of α-pinene, no difference in germination amongst the treated seeds was observed compared to control (except for *R. crispus*). However, at higher concentrations (15 and 20 µl/Petri), the seed germination of the weed species was significantly reduced in response to α-pinene compared to control. It appeared that 1,8-cineole and α-pinene were ineffective on inhibiting seed germination at low concentrations and require to have a higher concentration to cause complete inhibition in seed germination of test weed species.

Table 4.
Effect of different concentration of laurel essential oil and its main components, 1,8-cineole and α-pinene, on the seed germination of tested weeds

| Treatments | Treatment rate (µl/Petri dish) | Germination rate (%) ± Standard Error* | | | |
|---|---|---|---|---|---|
| | | *Amaranthus retroflexus* | *Glcycrrhiza glabra* | *Rumex crispus* | *Physalis angulata* |
| Laurel essential oil | 5 | 16.7±6.0 B c | 53.3±6.7 B a | 31.7±1.7 B bc | 36.7±3.3 B ab |
| | 10 | 8.3±6.0 BC b | 31.3±5.9 C a | 13.3±3.3 C b | 10.0±0 C b |
| | 15 | 0±0 C b | 0±0 D b | 13.3 ±3.3 C a | 0±0 D b |
| | 20 | 0±0 C b | 0±0 D b | 10.0±0 C a | 0±0 D b |
| 1,8-cineole | 5 | 73.3±3.3 A a | 0±0 D d | 33.3±3.3 B c | 56.7±3.3 B b |
| | 10 | 23.3±1.7 B b | 0±0 D d | 13.3±3.3 C c | 53.3±3.3 B a |
| | 15 | 10.0±5.0 C b | 0±0 D c | 13.3±3.3 C b | 50.0±0 B a |
| | 20 | 0±0 D b | 0±0 D b | 10±5.8 C a | 13.3±3.3 C a |
| α-pinene | 5 | 61.7±4.4 A a | 60.0±0 AB a | 26.7±6.7 B b | 76.7±6.7 A a |
| | 10 | 33.3±7.3 B bc | 46.7±6.7 BC ab | 26.7±3.3 B c | 56.7±3.3 B a |
| | 15 | 23.3±6.0 B ab | 33.3±6.7 C a | 16.7±3.3 BC b | 10.0±0 C b |
| | 20 | 21.7±4.4 B a | 31.3±5.9 C a | 6.7±3.3 C b | 0±0 D b |
| Control | 0 | 78.3 ±3.3 A ab | 73.3±6.7 A ab | 63.3 ±3.33A b | 80 ±5.8 A a |

*Satistical analyses were carried out on arcsin-transformed data and results were extrapolated to original data. Two-way ANOVA was applied for data analysis. Means within a column with the same upper-case letter and a row with the same lower-case letter are not significantly different at 1% level by LSD test.

The effect of different concentration of laurel essential oil and its main components, 1,8-cineol and α-pinene, on the seed germination of tested crop species is shown in Table 5. Laurel essential oil and its main

components, 1,8-cineole and α-pinene had a significant effect on seed germination of test crop species ($P$<0.01). Crop species responded differently to laurel essential oil, 1,8-cineole and α-pinene in the terms of seed germination. Laurel essential oil at low concentrations (5 and 10 µl/Petri dish) had no or very little effect on the germination of corn and wheat seeds, whereas its high concentrations (15 and 20 µl/Petri dish) completely inhibited germination in wheat and cotton seeds and significantly reduced in inhibiting seed germination of corn. Similarly 1,8-cineole at high concentrations completely inhibited seed germination of weed and cotton, while it caused significant decrease in inhibiting seed germination of corn. Contrary to the laurel essential oil and 1,8-cineole, α-pinene showed no inhibitory activity on seed germination of both wheat and corn with same germination percentage as compared to control. In case of cotton, germination significantly decreased with increasing in the concentration of α-pinene. It appeared that laurel essential oil and 1,8-cineole had a strong inhibitory activity on all test seeds (except lower concentrations of laurel essential oil and 1,8-cineole for corn), whereas α-pinene was totally ineffective on the seed germination of all the crop species except for the cotton seeds.

Table 5
Effect of different concentration of laurel essential oil and its main components, 1,8-cineol and α-pinene, on the seed germination of tested crop species

| Treatments | Treatment rate (µl/Petri dish) | Germination rate (%)±Standard Error* | | |
|---|---|---|---|---|
| | | Wheat | Corn | Cotton |
| Laurel essential oil | 5 | 90.0±0 B b | 100±0 A a | 26.6±0 B c |
| | 10 | 60.0±10.0 C b | 100±0 A a | 26.6±0 B c |
| | 15 | 0±0 D b | 46.7±6.7 B a | 0±0 C b |
| | 20 | 0±0 D b | 23.3±8.8 C a | 0±0 C b |
| 1,8-cineole | 5 | 63.3±6.7 B b | 100±0 A a | 26.7±6.7 B c |
| | 10 | 10±0 C b | 80±11.5 B a | 13.3±6.7 B b |
| | 15 | 0±0 D b | 46.7±6.7 C a | 0±0 C b |
| | 20 | 0±0 D b | 23.3±8.8 C a | 0±0 C b |
| α-pinene | 5 | 100±0 A a | 100±0 A a | 66.7±6.7 B b |
| | 10 | 100±0 A a | 100±0 A a | 40±11.5 BC b |
| | 15 | 100±0 A a | 100±0 A a | 33.3±6.7 CD b |
| | 20 | 80±20 A a | 86.7±13.3 A a | 13.3±6.7 D b |
| Control | 0 | 100±0 A a | 100±0 A a | 100±0 A a |

*Satistical analyses were carried out on arcsin-transformed data and results were extrapolated to original data. Two-way ANOVA was applied for data analysis. Means within a column with the same upper-case letter and a row with the same lower-case letter are not significantly different at 1% level by LSD test.

The chemical composition of a plant product depends on the plant species, the plant part, the season (temperature, photoperiod, and hygrometry), the method of harvesting, the geographical zone, pedological conditions, and the method used to isolate the plant product. Therefore, the extract of the same species from different geographical areas and from various plant parts can be different in chemical composition. Andronikashvilli and Reichmuth (2002) reported laurel essential oil extracted from its leaves collected from the samples of Georgia essentially contained 1,8-cineole (40.74%), *α*-terpinyl acetate (17.81%), sabinene (5.72%), *α*-pinene (4.86%) and *B*-pinene (3.17%). However, the chemical composition and content of the main compounds of essential oils extracted from the leaves of *L. nobilis* in this study is different from those reported by Andronikashvilli and Reichmuth (2002). It indicated that the chemical composition of essential oils from different geographical areas varied.

Under appropriate conditions, allelochemicals may be released in quantities suppressive to developing weed seedlings (Wu et al., 2002). Due to their high volatility, many plant extracts and essential oils have been tested for inhibitory activity on seed germination of many weed species (Dudai et al., 1999; Singh et al., 2003). A variety of allelochemicals have been identified, including essential oils that inhibit seed germination and plant growth (Neori et al., 2000). Likewise, our study indicated that vapor of oregano and laurel essential oils had also inhibitory effect on seed germination of test weed species. However, both oregano and laurel essential oils indicated a remarkable difference in response to the weed species. Since laurel essential oil required higher concentrations to obtain complete inhibition of seed germination of the weeds, oregano essential oil was more toxic in inhibiting seed germination of some weeds than that of laurel essential oil. The results presented here are similar to those on inhibitory activity of volatile essential oil from a number of aromatic plants on seed germination of various weed species (Dudai et al., 1999; Angelini et al., 2003; Singh et al., 2003).

The mechanisms by which oregano essential oil completely inhibit seed germination remain unkown. However, some studies have indicated that volatile oxygenated monoterpenes, such as cineole, are potent inhibitors of mitosis (Baum et al., 1998; Romagni et al., 2000). Vaughn (1991) reported that essential oils from cinnamon (*Cinamommum zeylanicum* Blume) and red

thyme (*Thymus vulgaris*) inhibit potato sprout growth by killing meristematic cells. Lorber and Muller (1976) reported that roots exposed to monoterpene vapours exhibited a variety of membrane fragments and absence of intact organelles, thereby indicating a structural breakdown in response to monoterpenes. All these reports indicated that probably loss or disruption of mitotic activity might also be responsible for the observed reduction or the inhibition of germination as observed in present study.

Terpenoids, particularly oxygenated monoterpenes and sesquiterpenes, are the main components of essential oils and are often responsible for their inhibitory activity. Since carvacrol completely inhibited seed germination in all species, showing a behavior similar to that of oregano essential oil, it would be the sole ingredient responsible for inhibitory activity shown to be exerted by oregano essential oil. Similar results were reported by Angelini et al. (2003), Dudai et al. (1999) and Singh et al. (2003). Comprasion between the activity of laurel essential oil and that of its pure constituents suggests that both laurel essential oil and its constituents, 1,8-cineole and α-pinene, indicated a remarkable difference in response to the weed species. While 1,8-cineole and α-pinene had same response to *R. crispus* with laurel essential oil, only in the case of *G. glabra* did 1,8-cineole completely inhibit seed germination. Therefore, they can not be the only components responsible for inhibiting activity on the weed species, particularly *A. retroflexus* and *P.angulata*. These compounds or the other constituent monoterpenes (*α*-terpinyl acetate, sabinene, *B*-pinene) may be acting synergistically like other allelochemicals (Einhellig, 1996).

Selectivity is one of the main properties in developing novel herbicide for weed management system. In this study, the germination trials for crop species showed that oregano and carvacrol were totally ineffective on cotton and corn germination, whereas they had a strong inhibitory activity on wheat seeds. On the other hand, laurel essential oil and 1,8-cineole had a strong inhibitory activity on all the test seeds (except for their lower concentrations for corn), whereas α-pinene was totally not effective on seed germination of all crop species except the cotton seeds. Therefore, it appeared that both oregano essential oil and carvacrol were more selective than both laurel essential oil and its main components, 1,8-cineole and α-pinene. As similar to our results, Angelini et al. (2003) reported that carvacrol was more selective as it did not inhibit radish germination. Dudai et al. (1999) reported that oregano (*O. syriacum* L.) essential oil was very effective on the inhibiting of seed germination of the wheat as similarly determined in our study.

## 4. Conclusions

From present study, it could be concluded that volatile oil from *O. syriacum* and carvacrol showed a strong inhibitory activity against the seed germination of the weed species and had selective action on various crop species. These data, therefore, suggested that oregano essentials oil could be used as bio-herbicide to inhibit emergence of weeds in agro-agriculture system. Future experiments on the possible effects of the periods of time during which such compounds are present in soil, possible structural modifications with consequent loss or acquisition of activity, allelopathic action on weed seeds in field conditions and formulation of essential oil for application are still needed to be studied in agriculture area.

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# Modeling Soil Profile Salinity with HYDRUS-1D

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**ABSTRACT**

Salt accumulation within the root zone significantly effects plant growth and development in arid and semi-arid regions. Today, use of low-quality irrigation water in agricultural production is increasing rapidly, because of continuous depletion and pollution of water resources. This means more salt transferred to the soil profile. It is of great importance to predetermine the effects of irrigation practices for sustainable crop production. For this purpose, models and tools that can produce reliable and fast results should be used.

In this study, soil profile salinity was modeled with the HYDRUS-1D software. In present study, Three different irrigation water salinity levels (S1=0.25 – control/municipal tap water, S2=1.5, S3=3.0 dS m-1) and 4 different irrigation volumes (leaching ratio) (LR1=10%, LR2= 20%, LR3=35%, LR4=50%) were modeled in a randomized plots factorial experimental design with 3 replications. Each treatment was carried out in individual PVC lysimeters with a length of 115 cm and a diameter of 40 cm in open-field to determine the efficiency of the model at different salinity levels and leaching rates. Alfalfa (Medicago sativa L.) was preferred as a plant due to its economic value, effective root depth and being a perennial plant. During the growing period, a total of 7 irrigations were practiced and five soil samples were taken from 20, 40, 60, 80 and 100 cm depths at the last day of each month.

Present findings revealed that values modeled with the HYDRUS-1D software were sufficient to determine the soil profile salinity. Relative error values (RE) ranged from 0.048 to 0.307. Increase in salinity and irrigation applications reduced the accuracy of the model. However, it can be said that the values produced by the model were sufficient even under the mentioned conditions. Especially for academic studies, the HYDRUS-1D software can be used to obtain fast and reliable results.

## 1. Introduction

Water is an essential component of agricultural production. Today, unconscious use of water resources and rapid pollution of existing resources resulted in water deficits and made it difficult to meet the water requirements of agricultural crops. To meet this demand, applications made with low quality irrigation water are increasing day by day.

As it is known, regardless of the water quality, there is some salt transferred to the soil profile through irrigations. The extent of this salt transfer increases with decreasing water quality used in irrigations. As many studies have shown, increase in salt accumulation in the soil profile causes yield loss in plant production. As a result of the continuation of applications with low irrigation water quality, sustainability of the soil profile for cultivation practices may be restricted or even become completely impossible. With a good drainage system and leaching practices, salinity factors can be removed from the soil profile. However, determining the salt loads carried by the drainage waters is of vital importance for the sustainability of the discharged water resources. For a sustainable agriculture, it is imperative to determine each parameter of this cycle and to take the necessary precautions.

Salinity, particularly in arid and semi-arid climates, is the event that soluble salts that leached and mixed with groundwater come to the soil surface through capillary rise together with high ground water table and salt accumulation over the soil surface and near the surface through evaporation and separation of water from the soil (Ergene, 1982; Kwiatowsky, 1998).

Salinity and alkalinity continue to be a problem in many countries today. A few years after the initiation of irrigation in different parts of the world, salinity and alkalinity problems that have never been encountered before are revealed. In addition, when the necessary precautions are not taken in areas with salinity and

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alkalinity problems, the spread of these areas increase and the problem becomes more and more severe (Özcan and Çetin, 2000).

As a result of using low-quality water for irrigation, the balance between plant nutrients in the soil is disturbed, ions that are toxic to plants accumulate, soils become saline and/or alkaline (Burton and Hook, 1979; Kirkham, 1986). As a result, irrigation with low irrigation water quality increases salinity in irrigated agricultural areas and causes a decrease in crop production and also causes deterioration of the soil profile (Maas and Hoffman, 1977; Ben-Hur et al., 1998).

Water, which creates drainage problems in the soil, also creates the problem of salinity and alkalinity. Depending on the degree of salinity, plants cannot grow in these soils or only plants that can live in saline soils can develop (Oğuzer, 1995; Feng et al., 2003).

There is a dynamic equilibrium between the cations in the soil solution and the cations in the adsorption complex and the dissolved and precipitated salts. Soil salt levels exhibit great temporal and spatial variations. Such a variation manifests itself with differentiations in salt content in horizontal and vertical positions (Schofield and Kirkby, 2003; Çullu et al., 2002).

Mathematical simulation models that take into account various soil, climate and plant factors are seen as useful tools to determine the most appropriate management practices for saline conditions (Ramos et al., 2011; Rasouli et al., 2012). In the last few years, various analytical and numerical models have been developed to predict water and solute transfer between the soil surface and groundwater.

The HYDRUS-1D (Šimůnek et al., 2008) software package is one of the software developed to simulate water movement and solute transfer and has a widespread use all over the world.

In this study, mathematical models were used to determine the soil profile salinity. Determining the change in soil profile salinity after agricultural applications means pre-determining the necessary precautions to be taken in order to maintain soil and vegetative production. For this purpose, mathematical models yield fast results. In this study, suitability of the HYDRUS-1D software was assessed.

## 2. Materials and Methods

The HYDRUS-1D software was used to model the soil profile salinity. In present study, 3 different irrigation water salinity levels (S1=0.25 – control/municipal tap water, S2=1.5, S3=3.0 dS m-1) and 4 different irrigation volumes (leaching ratio) (LR1=10%, LR2= 20%, LR3=35%, LR4=50%) were modeled in a randomized plots factorial experimental design with 3 replications. Each treatment was carried out in individual PVC lysimeters with a length of 115 cm and a diameter of 40 cm in open field. Lysimeters were placed on wooden grids placed on the soil and plastic containers were placed under them to collect drainage water. In order to increase the drainage efficiency, the lower parts of the lysimeters were filled with approximately 5 cm of gravel. After each irrigation, the drainage waters were taken immediately, and care was taken to avoid capillary rise. As a plant to be grown, clover was preferred because it has a long effective root depth and is a perennial plant.

Experimental soils have sandy-clay-loam (SCL) texture with a sand content of 58%, silt content of 21% and clay content of 21%. The soil and irrigation water properties used as input to the model are given in Table 1. Meteorological data, which is another input of the model, were taken from the 9th Regional Directorate Station of the General Directorate of Meteorology, Ministry of Environment, Urbanization and Climate Change.

During the growing season, irrigations were initiated on 14$^{th}$ of June. Subsequent irrigations were respectively practiced on 2$^{nd}$ of July, 20$^{th}$ of July, 9$^{th}$ of August, 26$^{th}$ of August, 8$^{th}$ of September and 27$^{th}$ of September (a total of 7 irrigations). Soil samples were taken in May as to represent the initial soil and a total of 5 soil samples were taken in the last days of the following months. Soil samples were taken from the depths of 20, 40, 60, 80 and 100 cm. The soil samples taken were air-dried and 1:2.5 saturation extract was obtained. Total salinity (EC) of the resultant saturation extracts was determined with an electrical conductivity instrument (YSI 3000) at 25$^{o}$C in accordance with the principles stated in Anonymous (1954).

Soil salinity values obtained as a result of the analyzes were compared with the model values using "mean absolute error" (MAE), "root mean square error" (RMSE) and "relative error" (RE) statistics. These equations are given below;

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|O_i - P_i| \qquad (1)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(O_i - P_i)^2}{n-1}} \qquad (2)$$

$$RE = \frac{RMSE}{Obs_{avg}} \qquad (3)$$

Table 1
Soil and irrigation water characteristics used as model input

| Soil and irrigation water ion content used in the model (mmolc $L^{-1}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | EC (dS $m^{-1}$) | Alk. | $Na^+$ | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ | $HCO_3^-$ | $SO_4^{2-}$ | $Cl^-$ | Tracer |
| Soil | 7,02 | 0,81 | 4,60 | 1,48 | 0,28 | 4,9 | 2,27 | 4,6 | 3,05 | 1,28 | 0 |
| Irr. Water (S1) | 7,08 | 0,25 | 1,60 | 0,45 | 0,07 | 0,73 | 1,22 | 1,55 | 0,31 | 0,62 | 0 |
| Irr. Water (S2) | 6,97 | 1,56 | 1,90 | 2,47 | 0,51 | 10,4 | 2,8 | 5,66 | 1,16 | 9,57 | 0 |
| Irr. Water (S3) | 6,86 | 3,06 | 1,90 | 3,69 | 0,76 | 21,17 | 5,42 | 10,47 | 3,05 | 17,19 | 0 |

| Physical and chemical soil characteristics (initial conditions) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sand (%) | | Clay (%) | | Silt (%) | | Texture | | Bulk density (g $cm^{-3}$) | | SAR $(mmol_{(c)}\ L^{-1})^{0,5}$ |
| 58 | | 21 | | 21 | | SCL | | 1,31 | | 0,78 |
| Soil hydraulic parameters | | | | | | Exc. cations, $mmol_{(c)}\ Kg^{-1}$ | | | | |
| Ks (cm $day^{-1}$) | α | N | $\Theta_r$ | $\Theta_s$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | CEC | $(mmol_{(c)}\ Kg^{-1})$ |
| 31,44 | 0.059 | 1,48 | 0,10 | 0,39 | 125,85 | 41,35 | 4,85 | 4,00 | | 177,15 |

where, Oi is the observed data; Pi is the data obtained as a result of the model; N is the number of observations; Obsavg is the average of the observed values.

It is generally expected to find as RMSE ≥ MAE. The small difference between the RMSE and MAE indicates the compatibility of the observation results with the predicted results (Legates and McCabe, 1999; Kobayashi and Salam, 2000). RE can be used to determine the accuracy of RMSE values. If the RE value is less than 10%, the model produced excellent results; between 10 - 20%, the model produced good results, and between 20 - 30%, the model produced poor results. If the RE value is more than 30%, the model produced poor results (Loague and Green, 1991).

Table 2
Statistical analysis results

| | May | | | June | | | July | | | August | | | September | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MAE | RMSE | RE | MAE | RMSE | RE | MAE | RMSE | RE | MAE | RMSE | RE | MAE | RMSE | RE |
| Monthly | 0,04 | 0,05 | 0,13 | 0,24 | 0,33 | 0,20 | 0,26 | 0,34 | 0,17 | 0,22 | 0,30 | 0,16 | 0,19 | 0,27 | 0,13 |
| S1LR1 | 0,02 | 0,03 | 0,11 | 0,03 | 0,04 | 0,14 | 0,03 | 0,04 | 0,12 | 0,03 | 0,04 | 0,14 | 0,02 | 0,03 | 0,08 |
| S1LR2 | 0,02 | 0,04 | 0,13 | 0,03 | 0,05 | 0,16 | 0,03 | 0,04 | 0,16 | 0,02 | 0,02 | 0,08 | 0,03 | 0,04 | 0,10 |
| S1LR3 | 0,01 | 0,02 | 0,06 | 0,04 | 0,04 | 0,15 | 0,02 | 0,02 | 0,07 | 0,03 | 0,04 | 0,15 | 0,02 | 0,02 | 0,07 |
| S1LR4 | 0,05 | 0,08 | 0,25 | 0,02 | 0,03 | 0,09 | 0,01 | 0,02 | 0,07 | 0,01 | 0,01 | 0,05 | 0,03 | 0,04 | 0,12 |
| S2LR1 | 0,04 | 0,05 | 0,14 | 0,38 | 0,47 | 0,30 | 0,34 | 0,44 | 0,17 | 0,22 | 0,28 | 0,12 | 0,37 | 0,46 | 0,19 |
| S2LR2 | 0,02 | 0,02 | 0,06 | 0,31 | 0,38 | 0,21 | 0,37 | 0,43 | 0,17 | 0,34 | 0,42 | 0,21 | 0,22 | 0,35 | 0,17 |
| S2LR3 | 0,04 | 0,06 | 0,16 | 0,30 | 0,36 | 0,20 | 0,41 | 0,49 | 0,28 | 0,43 | 0,50 | 0,27 | 0,25 | 0,34 | 0,19 |
| S2LR4 | 0,04 | 0,05 | 0,15 | 0,27 | 0,34 | 0,19 | 0,42 | 0,48 | 0,26 | 0,37 | 0,43 | 0,31 | 0,29 | 0,33 | 0,22 |
| S3LR1 | 0,07 | 0,08 | 0,19 | 0,36 | 0,49 | 0,19 | 0,45 | 0,53 | 0,14 | 0,41 | 0,48 | 0,13 | 0,28 | 0,42 | 0,10 |
| S3LR2 | 0,02 | 0,02 | 0,05 | 0,33 | 0,46 | 0,17 | 0,33 | 0,47 | 0,13 | 0,38 | 0,45 | 0,13 | 0,23 | 0,28 | 0,07 |
| S3LR3 | 0,04 | 0,05 | 0,13 | 0,50 | 0,60 | 0,20 | 0,43 | 0,51 | 0,16 | 0,28 | 0,33 | 0,10 | 0,24 | 0,36 | 0,09 |
| S3LR4 | 0,05 | 0,07 | 0,15 | 0,31 | 0,38 | 0,12 | 0,24 | 0,36 | 0,10 | 0,18 | 0,22 | 0,07 | 0,24 | 0,33 | 0,11 |

## 3. Results and Discussion

The simulation of the solute movement within the soil profile was made for the dates between 1 May and 30 September with the HYDRUS-1D mathematical model. Soil salinities between these dates were simulated by the model and these values were compared with the salinity values calculated for the soil samples taken in monthly periods. Model and monthly measurement values were compared based on salinity and leaching treatments and the relations between them were examined by using the statistics given in Equations 1, 2 and 3 (Yurtseven et al., 2013). Statistical results are given in Table 2. The graphs of the models and measurement values based on salinity and leaching treatments are given in Figure 1-5. The graph created with the average of the salinity treatments of the model and measurement values to observe the change of soil profile salinity during the growing period is given in Figure 6.

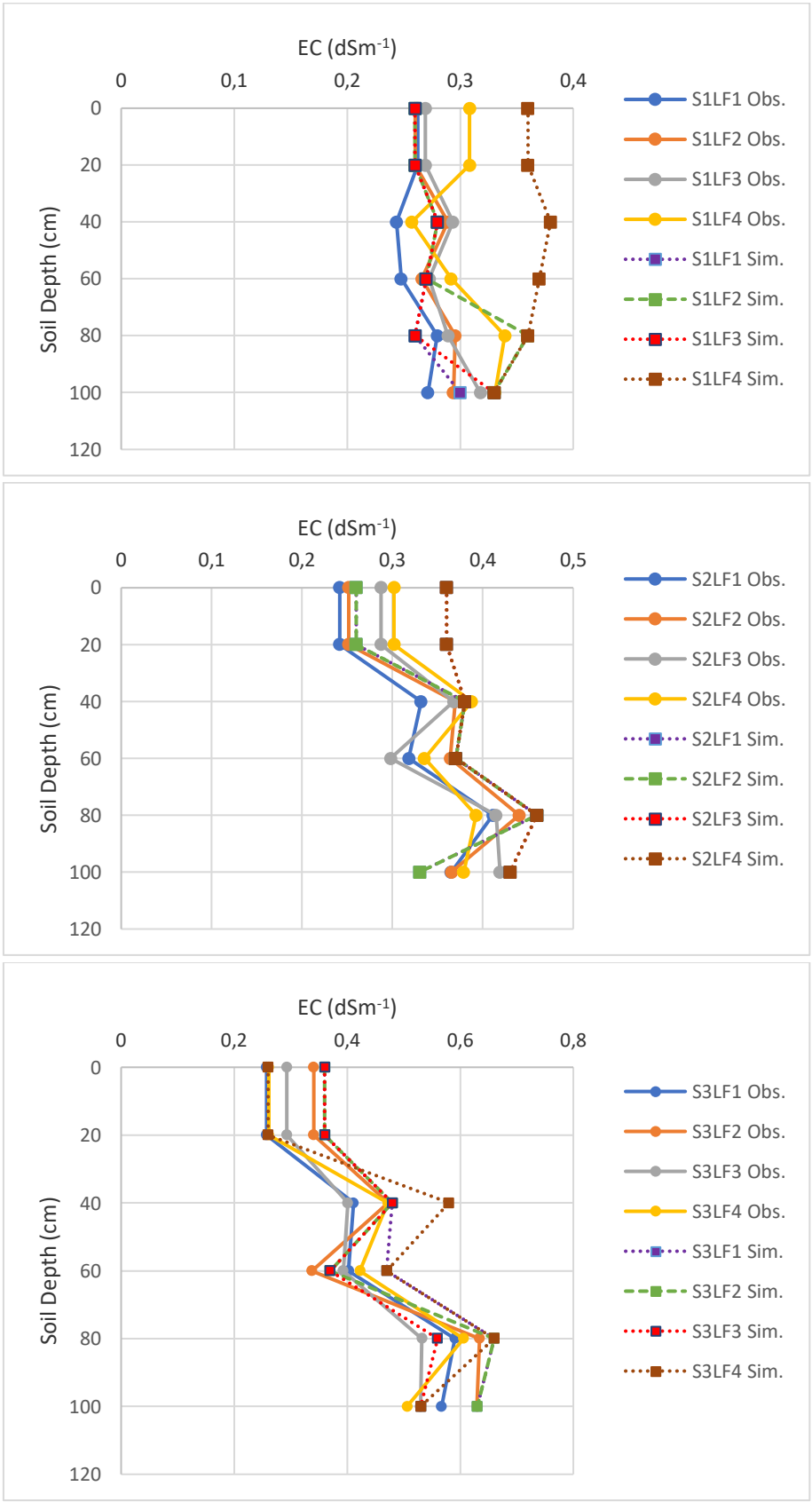


Figure 1
Change in salinity of soil profile in May based on salinity and leaching treatments

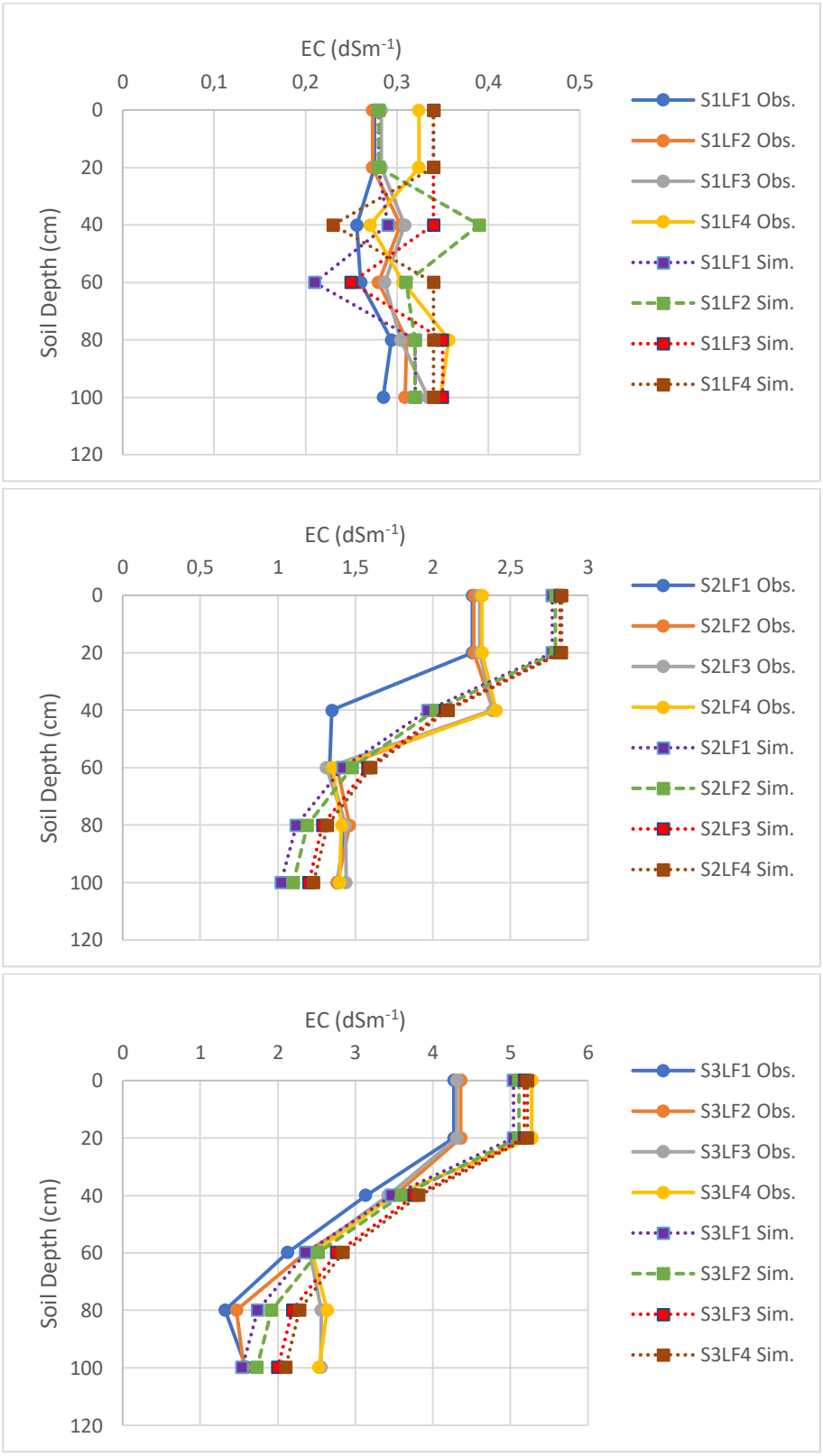


Figure 2
Change in salinity of soil profile in June based on salinity and leaching treatments

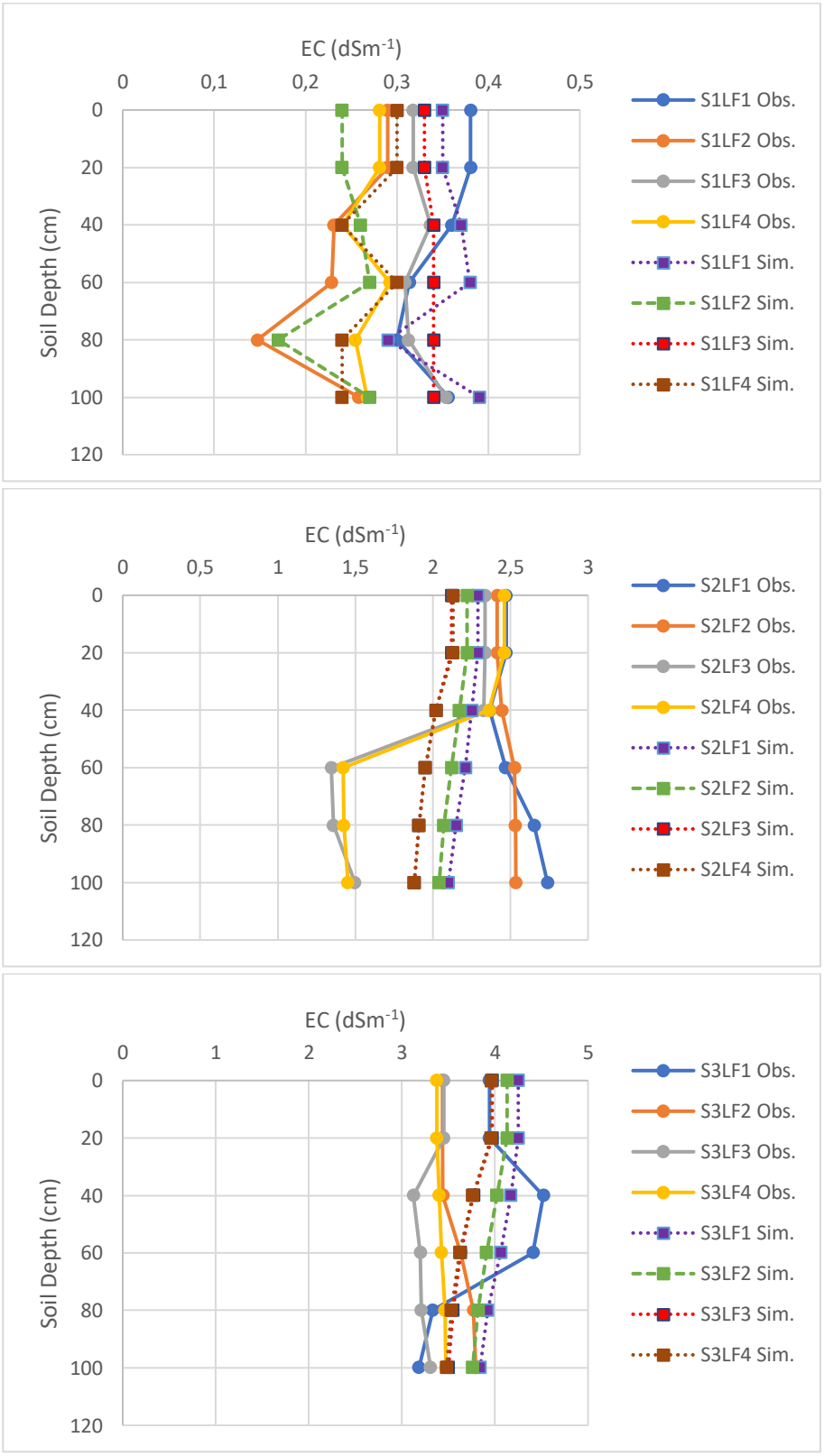


Figure 3
Change in salinity of soil profile in July based on salinity and leaching treatments

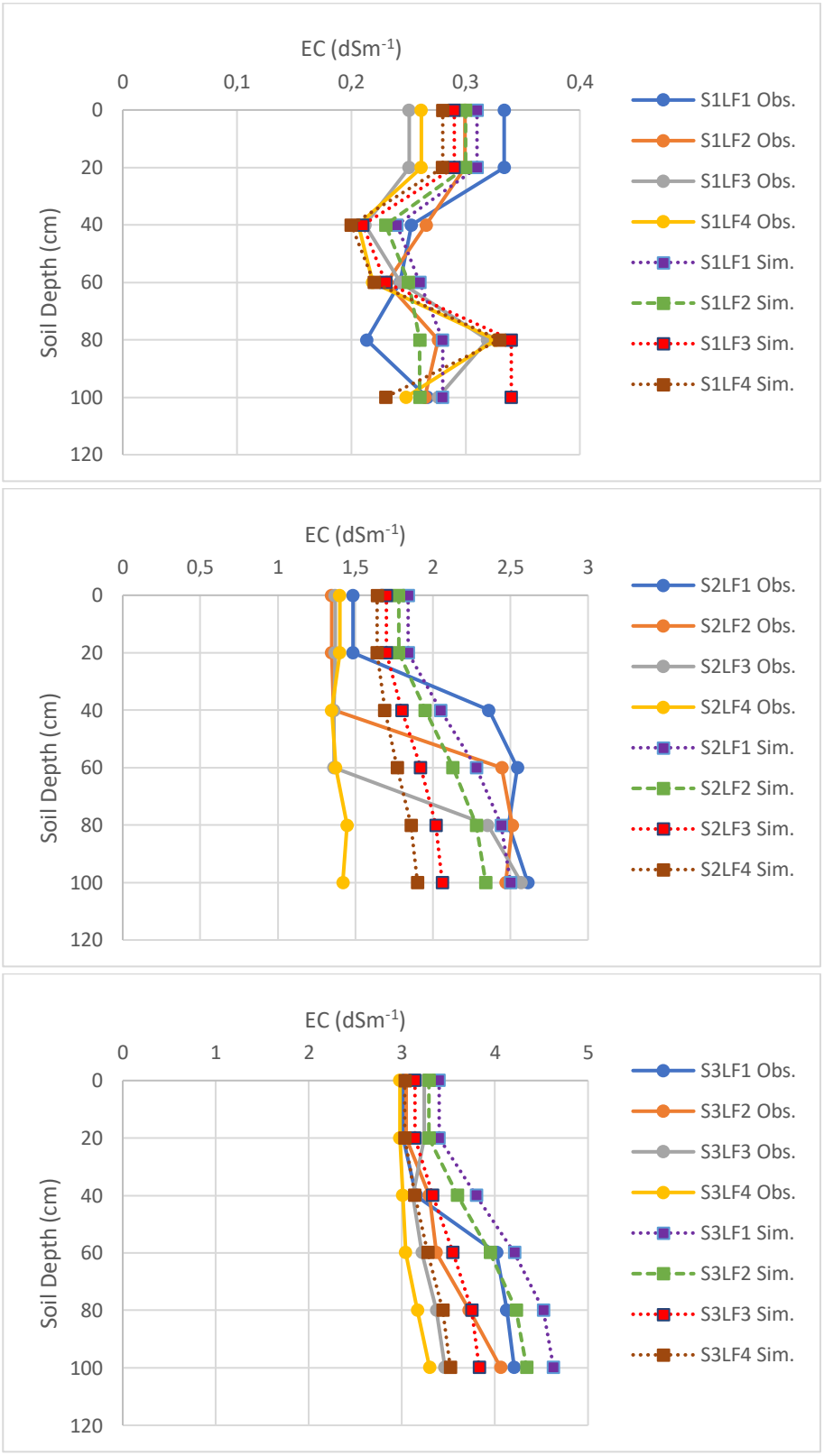


Figure 4
Change in salinity of soil profile in August based on salinity and leaching treatments

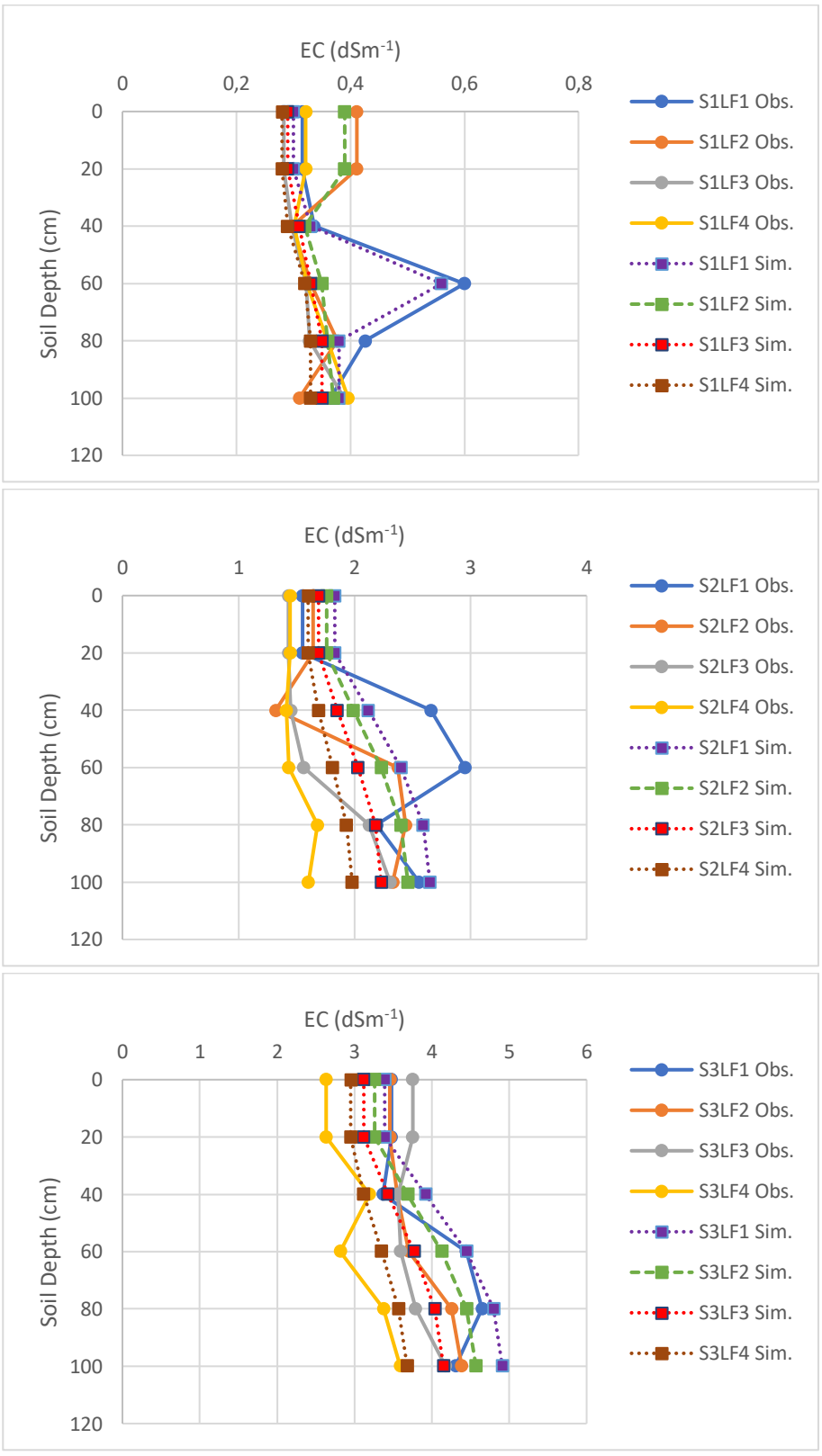


Figure 5
Change in salinity of soil profile in September based on salinity and leaching treatments

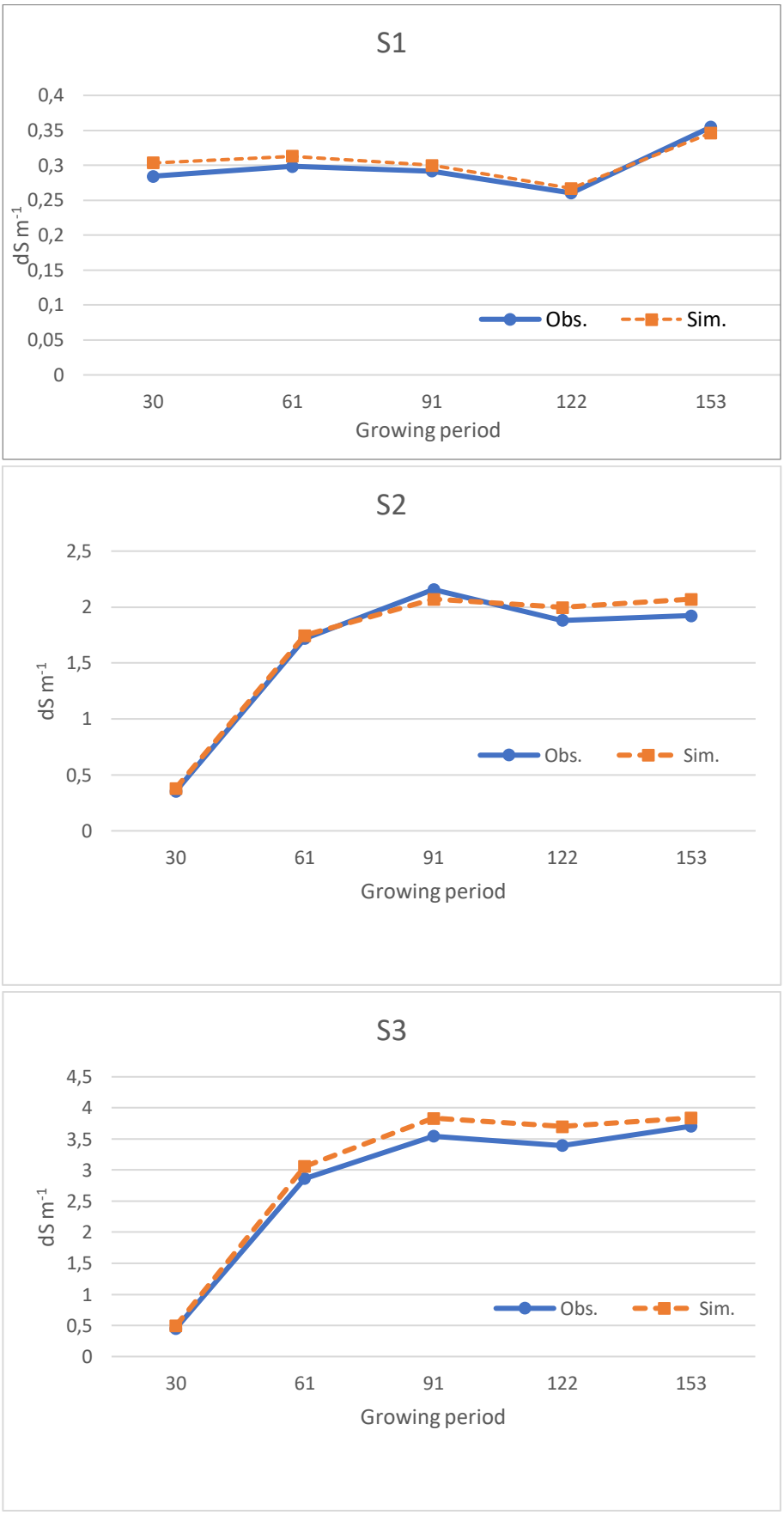


Figure 6
Variation of salinity treatments with the growing period

MAE values varied between 0.074 - 0.497, RMSE values between 0.085 - 0.600 and RE values between 0.221 - 0.307. When the statistical analysis results for the values produced and measured by the model independent of salinity and leaching treatments were analyzed on a monthly basis, it was seen that the lowest values were obtained in May. It was observed that the highest MAE, RMSE and RE values were obtained especially in the months when the irrigation applications increased. Increased RE values indicate that the accuracy of the model decreased. Increasing irrigation applications decreased the accuracy of the values produced by the model. However, statistical analysis results showed that the present model yielded good outcomes even in the months with intensive irrigation practices.

When the graphs obtained according to salinity treatments were examined, it was seen that the values produced by the model were higher for almost every salinity treatment. On the other hand, it was seen that the trend of change in soil salinity during the growing period was predicted in a similar way by the model. When the statistical analysis results were examined, it was seen that MAE, RMSE and RE values were the lowest in T1 treatments, which has the lowest salinity. This is an indication that the values produced by the model yielded better results in irrigation applications where salinity values were low.

## 4. Conclusion

Present findings revealed that the HYDRUS -1D software was suitable for modeling soil profile salinity. However, it was observed that the accuracy of the model decreased with increasing irrigation applications and salinity levels of the irrigation water. However, even in these cases, the model results obtained were found to be statistically appropriate. It can be said that the HYDRUS model will be very useful to use in laboratory and field experiments to determine soil profile salinity. However, it would be appropriate to use it to predict the soil profile salinity after agricultural production and to take the necessary precautions. The software is offered to researchers free of charge and that makes the software as the most widely used one among the modeling programs in which soil water movement and mineral substance transport is carried out.

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# Determination of Energy Use Efficiency and Greenhouse Gas Emission (GHG) of Cotton Cultivation in Batman Province: A Case Study from Beşiri District

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**ABSTRACT**

In this research, the energy use efficiency (EUE) and greenhouse gas emissions (GHG) of cotton cultivation in Beşiri district of Batman province in Turkey were determined. This research was conducted through face-to-face surveys with 64 farms selected by simple random sampling method in the 2018-2019 cultivation season. The energy input (EI) and energy output (EO) in cotton cultivation were calculated as 52,302.62 MJ/ha and 60,341.03 MJ/ha. Energy inputs consist of electricity energy with 19,948.86 MJ/ha(38.14%), chemical fertilizers energy with 14,163.83 MJ/ha (27.08%), diesel fuel energy with 13,218.49 (25.27%), irrigation water energy with 2563.79 MJ/ha(4.90%), machinery energy with 1071.14 MJ/ha(2.05%), chemicals energy with 797.96 MJ/ha (1.53%), seed energy with 291.46 MJ/ha (0.56%) and human labour energy with 247.09 MJ/ha(0.47%), respectively. Total energy inputs in cotton cultivation can be categorized as 68.79% direct, 31.21% indirect, 5.93% renewable and 94.07% non-renewable. EUE, specific energy (SE), energy productivity (EP) and net energy (NE) in cotton cultivation were calculated as 1.15, 10.23 MJ/kg, 0.10 kg /MJ and 8038.41 MJ/ ha, respectively. Total GHG was calculated as 3742.59 $kgCO_{2\text{-eq}}$ $ha^{-1}$ for cotton cultivation with the greatest share taken by nitrogen (26.19%). Nitrogen was followed by electricity (24.73%), irrigation water (18.48%), diesel fuel (17.31%), seed (5.04%), chemicals (2.93%), phosphorous (2.74%), human labour (2.36%), potassium (0.19%) and machinery (0.03%), respectively. GHG ratio value was calculated as 0.73 $kgCO_{2\text{-eq}}$ $kg^{-1}$ in cotton cultivation.

## 1. Introduction

The cotton plant has a widespread use and its use is often mandatory. It has great economic importance for the producing countries with the added value and employment opportunities it creates. Few countries in the world have ecology suitable for cotton farming. For this reason, approximately 80% of world production is carried out by a small number of countries, including Turkey (Anonym 2019). According to the predictions of the International Cotton Advisory Board (ICAC) for the 2021/22 season, world cotton cultivation areas are 33.2 million ha, yield is 775 kg/ha, and cotton production is 25.7 million tons. It is estimated that the USA will have the largest share in the increase in production, increasing it to 3.96 million tons with an increase of 780 thousand tons compared to the previous season (ICAC 2021; Anonym 2022a). According to ICAC data, cotton consumption in Turkey in 2018/19 season is estimated to increase by 10% compared to the previous year and reach 1.6 million tons. With a production of this scale, Turkey will rank 5th in world cotton consumption. Almost all of the cotton cultivation in Turkey is carried out in the Aegean Region, Southeastern Anatolia Region, Çukurova and Antalya regions (Anonym 2019). Batman / Beşiri district, where the research was conducted, is located in the Southeastern Anatolia Region (Anonym 2022b).

Global warming is the most burning problem of the current century. It is described as the continuous rise in the average temperature of Earth's atmosphere and oceans and is caused by increased concentrations of greenhouse gases in the atmosphere, which are caused by human activities such as deforestation and burning of fossil fuels. On a scientific level, there is a consensus that global warming will continue to be one of the most significant environmental challenges in the future. There is no doubt that greenhouse gases (GHG) originate from fossil fuel consumption (Pathak and Wassmann 2007; Pishgar-Komleh et al. 2012a). Agricultural production

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in greenhouse is the most intensive global method, owing to its high yield and high amount of energy consumption per hectare (Sethi and Sharma 2007; Pishgar-Komleh et al. 2013). Agricultural production is conducted by using various input types, which consequently lead to some output energies and greenhouse gases (GHGs) in the process. Therefore, energy balance in agricultural crops and GHG emission arising from inputs are as important as the economic aspects of agricultural products. The type of crop has an impact on determining energy use and productivity of agricultural crops (Tsatsarelis, 1991; Afzalinia 2020).

There is no doubt that excessive use of fossil fuels, agrochemicals, machinery, electricity and other such inputs with the sole purpose of achieving a significant increase in food and fibre yield and improving nutrition has led to agricultural intensification. But on the other hand, extensive use of energy poses a threat to human health and the environment. Hence, a precondition of a sustainable agriculture is to ensure more efficient use of energy (Yilmaz et al. 2005; Kazemi et al. 2018). Getting to know the dynamics of energy usage in agricultural production is critical. Energy related problems are too many to mention but the main ones could probably be listed as insufficient resources, high production costs, erroneous resource allocation and the ever-growing national and international competition in agricultural trade. Hence, awareness of such restrictions is vital when it comes to implementing a sustainable agricultural production and self- sufficient resource allocation in cotton production (Dagistan et al. 2009). The efficiency and environmental impacts of a production system is usually determined through an energy input-output analysis. The results of such an analysis are important as they can be used to make the necessary improvements to ensure a more efficient and environment-friendly production system (Ozkan et al. 2003, Ozkan et al. 2004a; Oren and Akturk 2006).

Studies on EUE and GHG emissions have been made and continue to be done in the world and in Turkey. The examples include cotton (Singh et al. 2000; Yilmaz et al. 2005; Oren and Ozturk 2006; Kousar et al. 2006; Dagistan et al. 2009; Khan et al. 2009; Zahedi et al. 2014; Kazemi et al. 2018; Sami and Reyhani 2018; Semerci et al. 2019; Afzalinia 2020), tobacco (Moraditochaee 2012; Loghmanpour-zarini and Abedi-firouzjaee 2013; Baran and Gokdogan 2015), sugar beet (Hacıseferoğulları et al. 2003; Erdal et al. 2007; Baran and Gokdogan 2016), potato (Mohammadi et al. 2008; Pishgar-Komleh et al. 2012a; Gokdogan et al. 2018), sunflower (Baran et al. 2016; Bayhan 2016; Akdemir et al. 2017), canola (Unakitan et al. 2010; Baran et al. 2014), olive (Guzman and Alonso 2008; Gökdoğan and Erdoğan 2021), soybean (Mandal et al. 2002) etc. In the current research, calculations have been made on the EUE of cotton production and the results have been used to make assessments. In the current research area, it is important to make a detailed research on the efficiency of energy use in cotton production and GHG emissions, as it contributes to the literature.

## 2. Materials and Methods

Batman province is located between 41° 10' and 41° 40' east longitudes and 38° 40' and 37° 50' north latitudes (Anonym 2022b). Beşiri district of Batman, where the research was conducted, is the closest district to the centre and is considered the centre of industry and agriculture in Batman (Anonym 2022c).

This research was carried out with cotton growing agricultural enterprises in Beşiri district of Batman province of Turkey for the 2018-2019 production season and the number of participating enterprises was calculated as 64 according to the simple random sampling method and face-to-face surveys, observations and field studies were conducted with these enterprises.

### *2.1 Sampling Method*

The formula (Eq. 1) of the method that was used to determine is given below (Çiçek and Erkan 1996).

$$n = \frac{N \times s^2 \times t^2}{(N-1)d^2 + (s^2 \times t^2)} \quad (1)$$

In the formula

n = Sample Size

s = Standard Deviation

t = "t value" Related to the Selected Confidence Limit

N = Total Number of Units for Sampling Frame

d = Acceptable margin of error (5%)

Agriculture and Forestry Directorate. previous studies have been used to calculate energy inputs and outputs and to determine the energy equivalent coefficients of inputs and outputs. The energy equivalents of the inputs and outputs used in agricultural production are given in Table 1. Energy output / input ratio (energy use efficiency), specific energy, energy productivity and net energy were calculated using the formulas given below (Equations 2-5) (Mandal et al. 2002; Mohammadi et al. 2008; 2010). All the data obtained in the research were transferred to the Excel program and evaluated.

$$\text{Energy use efficiency} = \frac{\text{Energy output } (\frac{MJ}{ha})}{\text{Energy input } (\frac{MJ}{ha})} \quad (2)$$

$$\text{Specific energy} = \frac{\text{Energy input } (\frac{MJ}{ha})}{\text{Yield output } (\frac{kg}{ha})} \quad (3)$$

$$\text{Energy productivity} = \frac{\text{Yield output } (\frac{kg}{ha})}{\text{Energy input } (\frac{MJ}{ha})} \quad (4)$$

$$\text{Net energy} = \text{Energy output} - \text{Energy input} \quad (5)$$

GHG values are calculated by multiplying the inputs with their GHG equivalent emission values. The results of the calculations are shown in Table 2. A production related GHG table has been composed and the GHG ratio calculation has been made. With regards to Karaağaç et al. (2019); the following formula (Eq. 6) adapted by Hughes et al. (2011) over the suggestion of was used to determine the GHG emission.

$$GHG_{ha} = \sum_{i=1}^{n} R(i)\, x\, EF(i) \quad (6)$$

$GHG_{ha}$: GHG ($kgCO_{2\text{-eş}}\ ha^{-1}$)

R(i): Application amount of (i) input ($unit_{input}\ ha^{-1}$)

EF(i) : GHG emission equivalent of (i) input ($kgCO_{2\text{-eq}}\ unit_{input}^{-1}$)

GHG ratio is an index defined as GHG emission quantity per kg yield. Calculation of GHG ratio has been based on the formula (Equation 7) given below and adapted by Karaağaç et al. (2019), Houshyar et al. (2015) and Khoshnevisan et al. (2014).

$$I_{GHG} = \frac{GHG_{ha}}{Y} \quad (7)$$

IGHG: GHG ratio (kgCO2-eş kg-1)

Y : Yield (kg/ ha)

Input energy is classified as direct, indirect, renewable and non-renewable. While indirect energy consists of pesticide and fertiliser, direct energy includes man and animal power, diesel and electric energy used during the production process. Non-renewable energy consists of oil, diesel, electric, chemicals, fertilisers and machinery. Renewable energy, on the other hand, includes man and animal power (Mandal et al. 2002; Singh et al. 2003; Koctürk and Engindeniz 2009). Energy balance, energy use efficiency calculations, energy input types and GHG calculations in cotton production are given in Table3-6.

Table 1
Energy equivalents used in agricultural production

| Inputs | Unit | Energy equivalent (MJ/unit) | References |
|---|---|---|---|
| Human labour | h | 1.96 | Mani et al. (2007); Karaağaç et al. (2011) |
| Machinery | h | 64.80 | Singh (2002); Kizilaslan (2009) |
| Chemicals | kg | 101.20 | Yaldiz et al. (1993); Ozkan et al. (2004b) |
| Chemical fertilizers | | | |
| Nitrogen | kg | 60.60 | Singh (2002); Demircan et al. (2006) |
| Phosphorus | kg | 11.10 | Mandal et al. (2002); Ozalp et al. (2018) |
| Potassium | kg | 6.70 | Mandal et al. (2002); Ozalp et al. (2018) |
| Micro elements | kg | 120 | Mandal et al. (2002); Singh (2002); Canakci and Akinci (2006); Banaeian et al. (2011) |
| Irrigation water | $m^3$ | 0.63 | Yaldiz et al. (1993); Demircan et al. (2006) |
| Electricity | kWh | 3.60 | Ozkan et al. (2004b) |
| Diesel fuel | l | 56.31 | Singh (2002); Demircan et al. (2006) |
| Seed | kg | 11.80 | Singh (2002); Yilmaz et al. (2005) |
| Output | | | |
| Cotton | kg | 11.80 | Singh (2002); Yilmaz et al. (2005) |

Table 2
GHG emissions coefficients in agriculture production*

| Inputs | Unit | GHG coefficients ($kgCO_{2\text{-eq}}\ unit^{-1}$) | References |
|---|---|---|---|
| Human labour | h | 0.700 | Nguyen and Hermansen (2012) |
| Machinery | MJ | 0.071 | Pishgar-Komleh et al. (2012a) |
| Chemicals | kg | 13.900 | BioGrace-II (2015) |
| Nitrogen | kg | 4.570 | BioGrace-II (2015) |
| Phosphorus | kg | 1.180 | BioGrace-II (2015) |
| Potassium | kg | 0.640 | BioGrace-II (2015) |
| Irrigation water | $m^3$ | 0.170 | Lal (2004) |
| Electricity | kWh | 0.167 | BioGrace-II (2015) |
| Diesel fuel | l | 2.760 | Clark et al. (2016) |
| Seed | kg | 7.630 | Clark et al. (2016) |

*Adapted from Eren et al. (2019)

## 3. Results and Discussion

The average cotton yield per hectare of the 64 cotton enterprises that took part in the research has been calculated as 5113.65 kg/ ha. Energy balance (EB) in cotton cultivation is given in Table 3. According to Table 2, the inputs in cotton production are electricity energy by 19,948.86 MJ/ha (38.14%), chemical fertilizers energy by 14,163.83 MJ/ ha (27.08%), diesel fuel energy by 13,218.49 MJ/ha (25.27%), irrigation water energy by 2563.79 MJ/ha (4.90%), machinery energy by 1071.14 MJ/ha (2.05%), chemicals energy by 797.96 MJ/ha (1.53%), seed energy by 291.46 MJ/ha (0.56%) and human labour energy by 247.09 MJ/ha (0.47%). Similar results were found in other researches on cotton cultivation. Semerci et al. (2019), Afzalinia (2020) calculated the ratio of electricity as 58.77% among the most used energy inputs. In other researches, Dagistan et al. (2009), Pishgar-Komleh et al. (2012b), Sami and Reyhani (2018) calculated the chemical fertilizers as the most used energy inputs.

Table 3
EB in cotton cultivation

| Inputs | Input used per hectare (unit / ha) | Energy value (MJ/ha) | Ratio (%) |
|---|---|---|---|
| Human labour | 126.07 | 247.09 | 0.47 |
| Machinery | 16.53 | 1071.14 | 2.05 |
| Chemicals | 7.89 | 797.96 | 1.53 |
| Chemical fertilizers | 313.50 | 14,163.83 | 27.08 |
| Nitrogen | 214.51 | 12,999.31 | 24.85 |
| Phosphorus | 87.02 | 965.92 | 1.85 |
| Potassium | 10.93 | 73.20 | 0.14 |
| Micro elements | 1.05 | 125.40 | 0.24 |
| Irrigation water | 4069.52 | 2563.79 | 4.90 |
| Electricity | 5541.35 | 19,948.86 | 38.14 |
| Diesel fuel | 234.75 | 13,218.49 | 25.27 |
| Seed | 24.70 | 291.46 | 0.56 |
| Total inputs | - | 52,302.62 | 100.00 |
| Output | Output per hectare (unit/ha) | Energy value (MJ/ ha) | Ratio (%) |
| Cotton | 5113.65 | 60,341.03 | 100.00 |
| Total output | - | 60,341.03 | 100.00 |

In this research, EUE, SE, EP and NE were calculated as 1.15, 10.23 MJ/kg, 0.10 kg/MJ and 8038.41 MJ/ha, respectively (Table 4). In other researches relating to cotton cultivation, Pishgar-Komleh et al (2012b) calculated EUE, SE, EP and NE as 1.85, 9.31 MJ/kg, 0.11 kg/ MJ and 27,218 MJ/ha; Zahedi et al. (2014) calculated EUE, SE, EP and NE as 0.7, 19.2 MJ/kg, 0.1 kg/MJ and -15,625.2 MJ/ha; Dagistan et al. (2009) calculated EUE, SE, EP and NE as 2.36, 4.99 MJ/kg, 0.20 kg/MJ and 26,663 MJ/ha; Sami and Reyhani (2018) calculated EUE, SE and EP as 1.21, 9.8 MJ/kg, 0.1 kg/MJ; Semerci et al. (2019) calculated EUE, SE, EP and NE as 1.11, 10.66 MJ/kg, 0.09 kg/MJ and 6136.29 MJ/ha$^{-1}$, respectively.

Table 4
Calculations of EUE in cotton cultivation

| Calculations | Unit | Values |
|---|---|---|
| Cotton | kg/ha | 5113.65 |
| Energy input | MJ/ha | 52,302.62 |
| Energy output | MJ/ha | 60,341.03 |
| Energy use efficiency | - | 1.15 |
| Specific energy | MJ/kg | 10.23 |
| Energy productivity | kg/MJ | 0.10 |
| Net energy | MJ/ha | 8038.41 |

The consumed total energy input was grouped as 68.79% DE, 31.21% IE, 5.93% RE and 94.07% N-RE (Table 5). Similarly, in other researches relating to cotton cultivation, Zahedi et al. (2014), Kazemi et al. (2018), Semerci et al. (2019), Afzalinia (2020), Baran et al. (2021) calculated DE ratio to be higher than IE. Similarly, N-RE energy ratio was calculated to be higher than RE by Dagistan et al. (2009), Yilmaz et al. (2010), Zahedi et al. (2014), Kazemi et al. (2018), Sami and Reyhani (2018), Semerci et al. (2019), Afzalinia (2020), Baran et al. (2021) in cotton cultivation.

Table 5
Calculations of energy input types in cotton cultivation

| Energy groups | Energy input (MJ/ha) | Ratio (%) |
|---|---|---|
| Direct energy[a] | 35,978.23 | 68.79 |
| Indirect energy[b] | 16,324.39 | 31.21 |
| Total | 52,302.62 | 100.00 |
| Renewable energy[c] | 3102.34 | 5.93 |
| Non-renewable energy[d] | 49,200.28 | 94.07 |
| Total | 52,302.62 | 100.00 |

[a]Includes human labour, diesel fuel, irrigation water and electricity,
[b]Includes machinery, chemical fertilizers, chemicals and seed,
[c]Includes human labour, irrigation water and seed,
[d]Includes machinery, diesel fuel, chemical fertilizers, chemicals and electricity.

The GHG emission values are shown in Table 6. Total GHG emissions were calculated as 3742.59 kg$CO_{2\text{-}eq}$ha$^{-1}$ for cotton cultivation and GHG ratio as 0.73. GHG emissions have been related to nitrogen by 26.19%, electricity by 24.73%, irrigation water usage by 18.48%, diesel fuel usage by 17.31%, seed usage by 5.04, chemicals usage by 2.93%, phosphorous usage by 2.74%, human labour usage by 2.36%, potassium usage by 0.19%

and machinery usage by 0.03%, respectively. A study conducted by Pishgar-Komleh et al (2012b) calculated the total GHG emission of cotton cultivation as 1195.25 $kgCO_{2\text{-}eq}ha^{-1}$, Sami and Reyhani (2018) calculated the total GHG emission of cotton cultivation as 2075.5 $kgCO_{2\text{-}eq}ha^{-1}$, Pishgar-Komleh et al (2012a) calculated the total GHG emission of potato production as 992.88 $kgCO_{2\text{-}eq}ha^{-1}$.

Table 6
GHG emissions in cotton cultivation

| Inputs | Unit | GHG coefficients ($kgCO_{2\text{-}eq}$ $unit^{-1}$) | Input (unit/ha) | GHG emissions ($kgCO_{2\text{-}eq}$ $ha^{-1}$) | Ratio (%) |
|---|---|---|---|---|---|
| Human labour | h | 0.700 | 126.07 | 88.25 | 2.36 |
| Machinery | MJ | 0.071 | 16.53 | 1.17 | 0.03 |
| Chemicals | kg | 13.900 | 7.89 | 109.60 | 2.93 |
| Nitrogen | kg | 4.570 | 214.51 | 980.31 | 26.19 |
| Phosphorus | kg | 1.180 | 87.02 | 102.68 | 2.74 |
| Potassium | kg | 0.640 | 10.93 | 6.99 | 0.19 |
| Irrigation water | $m^3$ | 0.170 | 4069.52 | 691.82 | 18.48 |
| Electricity | kWh | 0.167 | 5541.35 | 925.41 | 24.73 |
| Diesel fuel | l | 2.760 | 234.75 | 647.90 | 17.31 |
| Seed | kg | 7.630 | 24.70 | 188.46 | 5.04 |
| Total inputs | - | - | - | 3742.59 | 100.00 |
| GHG ratio | - | - | - | 0.73 | - |

## 4. Conclusions

The findings of this study can be summarised as follows.

In this research, total energy input and output were calculated as 52,302.62 and 60,341.03 MJ/ ha, respectively. The electricity energy, chemical fertilizers and diesel fuel had the highest share in energy usage for cotton cultivation, amounting to 19,948.86, 14,163.83, 13,218.49 MJ/ ha. EUE, SE, EP and NE were calculated as 1.15, 10.23 MJ/kg, 0.10 kg/MJ and 8038.41 MJ/ ha, respectively.

The consumed total energy input was grouped as 68.79% DE, 31.21% IE, 5.93% RE and 94.07% N-RE.

Total GHG emissions were calculated as 3742.59 $kgCO_{2\text{-}eq}ha^{-1}$ for cotton cultivation and GHG ratio as 0.73.

Efficiency usage of energy source is important to decrease operating cost and decrease emissions of air contaminants and greenhouse gases (Demirbas and Urkmez 2006; Mujeebu et al. 2009a; 2009b; Ekinci 2011). Taking the recommendations proposed by this study into consideration can contribute to better energy use efficiency in the future.

Decreasing electricity, chemical fertilizer and diesel fuel usage are the priorities in cotton cultivation for EUE. For this purpose, according to Pishgar-Komleh et al. (2012b), applying soil analysis to determine soil fertilizer needs (to reduce high chemical fertilizers energy utilization and GHG emission), matching equipment to tractors, fuel efficiency and applying minimum or zero tillage (to reduce diesel fuel utilization) is proposed.

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