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The effects of double-stemmed grafted tomato plants on yield and quality of tomato cultivation

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ABSTRACT

In this study, the effect of the production of double-stemmed grafted and non-grafted tomato plants on yield and quality was investigated. Android F_1 and Torry F_1 tomato (*S. lycopersicum* L.) cultivars were grafted on "Classmate" tomato rootstock, and grafting was doneaccording to one or two stems for treatments. There were 12 plants in each treatment over 4 grafting and 2 varieties and the plants were provided seedling nursery. The number of stems left in tomato seedlings as grafted and non-grafted was taken as the basis. The plants which are consisting of two stems are formed from the cotyledon axillary buds. The grafting in the experiment were created as follows;.1- grafted-double stem: Shoots were formed with the development of cotyledon axillary buds, 2- Non-grafted-double stem: Shoots were formed with the development of cotyledon axillary buds on cultivars, 3- Grafted-single stem and 4- non-grafted-single stem (control) were formed. In the experiment conducted, the highest plant height (167.25 cm) was obtained from the control treatment and the highest stem diameter (16.58 mm) was obtained from the grafted double stem treatment. *L* and Hue angel values measured in fruit color of treatments were not statistically significant. The highest total soluble solids (4.46%) was obtained from the non-grafted double stem treatment. In terms of total yield, the highest value (12.27 kg m^{-2}) was obtained in the control plants. The effect of double stem in cotyledon axillary buds on grafted tomato cultivation was found statistically significant on yield, and grafting with double stem decreased the yield, as compare to the control treatment.

1. Introduction

Grafted vegetable cultivation has been successfully applied in many Asian countries for years, and its use is increasing throughout the world. Watermelon and tomato are the two most commonly grafted vegetables worldwide. However, as stated by Lee and Oda (2003); grafting of herbaceous vegetables is an ancient practice. Grafting in Cucurbitaceae was briefly described in Korea in the seventeenth century by Hong (1643-1715), and then later adopted as a commercial production technology by many countries in Europe, the Middle East, North Africa, Central America and other Asian regions (Kumar et al. 2015). Grafting and budding are horticultural techniques used to join parts from two or more plants so that they appear to grow as a single plant. In grafting, the upper part (scion) of one plant grows on the root system (rootstock) of another plant (Anonymous 2023). One of the first reasons for using grafted seedlings is to prevent soil-borne diseases under the intensive production system. Grafting on suitable rootstocks can reduce the side effects of abiotic and biotic stresses such as salt, water, temperature, and heavy metals. Moreover, it has been observed that grafting increases water and nutrient usage values in tomato plants (Singh et al. 2017). The use of grafted seedlings in open field vegetable production exceeded 54% in Japan, 81% in Korea, 69% of greenhouse vegetable growing in Japan, and 81% in Korea (Kurata 1994). In Turkey, as stated by Tüzel et al. (2015); grafted seedling production increased 230 times between 1998-2013, while the number of firms producing grafted seedlings was 4 and the production amount was 500000 in 1998, the number of companies making grafted seedlings by the end of 2013 increased to 36 and the production amount increased to approximately 115 million. However, although growing hybrid tomato varieties in the greenhouse has gained worldwide popularity, the costs of producing grafted plants continues to be a deterrent for small-scale producers (Hanna 2012). Grafting techniques in vegetables have developed in the last decade due to the emergence of new techniques and materials. Grafted seedlings for plant growth is becoming an increasingly popular method in the vegetable industry. Despite these recent developments, the percentage of grafted vegetable plants is still relatively low. The most important reasons for this are; high cost of grafting, problems with the control of soil-borne pests and diseases, and the adaptation of grafted seedlings to abiotic stresses. The aim of this study was to investigate the effect of grafted and non-grafted double stems in cotyledon axillary buds on yield, quality, and plant growth on tomato cultivation.

2. Material and Methods

2.1. Materials

This study was conducted in a glass greenhouse in Akdeniz University Faculty of Agriculture Research and Treatment Field in the Fall season of 2018-2019. In the study, Android F_1 and Torry F_1 tomato cultivars were used on "Classmate" tomato rootstock.

2.2. Methods

There were 12 plants in each treatment over 4 grafting methods and 2 varieties, the plants were provided by the Ad-Rossen company and the number of stems left in tomato seedlings as grafted and non-grafted was taken as the basis. In plants consisting of two stems, shoots are formed from the axillary bud of cotyledon leaves. The grafting in the experiment was created as follows; 1. Grafted double stem: Shoots were formed with axillary bud development in cotyledon leaves. Non-grafted double stem: Shoots were formed with the development of the axillary bud in cotyledon leaves. Grafted-single stem and non-grafted single stem (control) were obtained on seedlings. The plants were spaced according to the double row planting systemon 25.09.2018, the planting distances were a wide row of 100 cm, a narrow row of 50 cm and 50 cm between plants within the row. Plants with double stems were planted in the middle of the double row as a single row and at a distance of 50 cm between plants within the row. Both shoots left to develop in plants were planted according to the double-row arrangement and the plants were supported by attaching them to the hanger rope. Apical bud removal was performed in plants after the 6th cluster, and the last harvest was carried out on 08.04.2019. In the seedlings planted according to the double-row and single-row planting system, the irrigation system was a single line for each plant with double stemmed and single-stemmed plants. The amount of fertilizer required for one ton of tomato yield in fertilization was calculated as 3.5 kg N, 1 kg P_2O_5 and 6 kg K_2O over the pure substance (Gianquinto et al. 2013). In the study; plant height, plant stem diameter, *L* and Hue angle (h°) for fruit color (Minolta Chroma Meter CR-400), total soluble solids (Brix°), pH, number of fruit in clusters and yield values were investigated.

2.3. Statistical analysis

The study had 4 replications according to the randomised block design pattern. After the ANOVA, the means of the treatments were compared according to the LSD test at the significance level of $P \leq 0.05$.

3. Results and Discussion

The effect of double-stem growing on cotyledon axillary buds in grafted and non-grafted tomatoes on plant growth development is given in Table 1. As can be seen in Table 1, the effects of grafting on plant height was found to be statistically significant. The highest plant length was in the control plants (167.25 cm) and the lowest value was obtained from grafted double stem plants (147.63 cm). The effects of grafting on plant stem diameter in grafted tomatoes were found to besignificant (Table 2).

In grafted double stem plants, the stem diameter of the plant was 16.58 mm, which is higher than other grafting. Findings obtained from Rahmatian et al. (2014) and Soare et al. (2018) showed similarity with the results. The effects of grafting and varieties on color values related to *L* and h° in tomato fruits were found to be statistically insignificant. The values are given in Table 3. The effect of the grafting on the total soluble solids in fruit juice was found to be statistically significant but no difference was found between the varieties. While the highest

Table 1. The effect of the different stem numbers on the plant height in grafted and non-grafted tomatoes (cm)

Varieties	Grafted double stem	Non-grafted double stem	Grafted single stem	Non-grafted single stem	Average (Variety)
Android F_1	141.75 d*	152.50 c	160.75 b	165.50 ab	155.13 B**
Torry F_1	153.50 c	165.00 ab	161.00 b	169.00 a	162.13 A
Average (Grafting)	147.63 C	158.75 B	160.88 B	167.25 A***	
LSD %5	(Graft.): 4.67	(Var.): 3.3	(Graft. x Var.): 6.6		

*Means in the interaction by the same letter are not significantly different ($P \leq 0.05$), **Means in the same column by the same letter are not significantly different ($P \leq 0.05$), ***Means in the same line by the same letter are not significantly different ($P \leq 0.05$).

Table 2. The effect of the different stem numbers on the diameter of the plant in grafted and non-grafted tomatoes (mm)

Varieties	Grafted double stem	Non-grafted double stem	Grafted single stem	Non-grafted single stem	Average (Variety)
Android F_1	17.00	15.35	15.48	15.80	15.91 A**
Torry F_1	16.15	15.35	15.28	14.18	15.24 B
Average (Grafting)	16.58 A*	15.35 B	15.36 B	14.99 B	
LSD %5	(Graft): 0.74	(Var.): 0.52	(Graft x Var.): ns		

*Means in the same line by the same letter are not significantly different ($P \leq 0.05$), ns: Non-significant, **Means in the same column by the same letter are not significantly different ($P \leq 0.05$).

Table 3. The effect of the different stem numbers on *L* color and h° value of fruits in grafted and non-grafted tomatoes

Varieties	Grafted double stem		Non-grafted double stem		Grafted single stem		Non-grafted single stem		Average (Variety)	
	L	h°	*L*	h°	*L*	h°	*L*	h°	*L*	h°
Android F_1	43.45	50.90	43.25	51.18	44.25	51.13	43.93	51.35	43.72	51.14
Torry F_1	44.23	51.43	43.70	51.68	44.18	53.43	43.23	50.45	43.83	51.74
Average (Grafting)	43.84	51.16	43.48	51.43	44.21	52.28	43.58	50.90		
LSD %5 (*L*)	(Graft): ns		(Var.): ns		(Graft x Var.): ns					
LSD %5 (h°)	(Graft): ns		(Var.): ns		(Graft x Var.): ns					

ns: Non-significant.

values of Brix were observed in non-grafted and grafted-double stem plants (4.46% and 4.35%), low values were obtained in control and grafted single stem grafting respectively (14.14% and 3.98%) (Table 4). These results are thought to be related to the high-water consumption coefficient due to mineral intake in double-stem plants. At the same time, a study by Rahmatian et al. (2014) showed that the number of stems does not affect the amount of total soluble solids in tomato. Colla et al. (2015) investigated the effect of grafted melons grown in salty conditions on yield, fruit quality and mineral composition and reported that the amount of Brix is higher in non-grafted plants compared to grafted plants. In a study by Qaryouti et al. (2007) with grafted and non-grafted tomato plants grown in a soil and soilless culture medium, it was noted that the value of Brix is lower in grafted tomato fruits grown in a soilless culture. In the results obtained by Neocleous (2010), who worked on the cultivation of grafted and non-grafted tomatoes in different environments, the Brix value was expressed as 4.9% in fruits taken from grafted plants and 5.5% in non-grafted plants. Abdulaziz et al. (2017) and Turkmen et al. (2010) reported that grafted tomatoes had increased amounts of Brix on different rootstocks. In grafted tomato cultivation, the effect of different stem grafting on the pH value of tomato juice was not found to be statistically significant. The acidity values of tomato juice varied between pH 4.51-4.68. Khah et al. (2006) and Yarsi (2011) obtained similar results and reported that the grafting on pH value of tomato fruit juice did not make any difference in grafted and non-grafted tomato cultivation. The effect of double stem formed in cotyledon axillary buds in grafted tomato cultivation on the number of fruits in the cluster was found to be statistically significant among the grafting in the “Android” tomato variety (Table 5). While the highest (4.15) values were obtained in the control and grafted single stem plants, the number of fruits was 3.98 in grafted double stem plants. The lowest number of fruits was obtained from grafted double stem plants (3.70 fruit number). In the Android tomato variety, the effect of fruit number between clusters in different grafting was found to be statistically significant. According to the values obtained, the highest number of fruits was determined in the first and second cluster (5.49, 5.21) and the least number of fruits (1.54) in the sixth cluster. Depending on the cluster, the effect of the grafting on the number of fruits in the cluster was found to be statistically significant (Table 5). According to the values obtained for “Torry“ cultivar (Table 6), the highest number of fruits was obtained from the first and second cluster (5.16, 5.04) and the least number of fruits was obtained from the sixth cluster (1.56). The effect of double stem in cotyledon axillary buds in grafted tomato cultivation on average fruit weight was not found to be statistically different between grafting and varieties (Table 7).

The results show compatibility with the findings of Oda et al. (1996), Qaryouti et al. (2007) and Soare et al. (2018). The effects of grafting on the total yield of tomatoes were found to be statistically significant and the highest yield values (12.27 kg m^{-2}) were obtained from the control plants (Table 8). These values were determined as 11.46 kg m^{-2}, 10.49 kg m^{-2} and 10.10 kg m^{-2} in single stem, grafted and non-grafted double stem grafting, respectively. There was no difference in total yield between varieties, but differences in treatment variety interactions were found to be significant. The highest yield was obtained from the control (12.67 kg m^{-2}) and single grafted (12.11 kg m^{-2}) treatments in Android F_1. The highest yield was also obtained from the control (11.86 kg m^{-2}) and grafted double (11.88 kg m^{-2}) treatments in Torry F_1. The grafted double stem plants had a low yield compared to the control plants, due to the stress caused by grafting. It is believed that grafted plants have a slow development and a partial delay in flowering and fruit set. The rootstock-scion compatibility in the vascular system can affect the yield negatively (Arpacı 2016). Traka-Mavrona et al. (2000) showed that it does not make a difference from the control plants on the yield of some pumpkin rootstock varieties in melon, and even revealed that it caused a significant decrease in the yield of some rootstocks. Kacjan-Marsic and Osvald (2004) investigated the effect of buds on tomato yield in a study where “Monro” and “Belle” cultivars used as a scion, “PG-3” and “Beaufort” cultivars. The combination of “Monro” / “Beaufort” from the rootstock scion treatment created a positive difference. In all grafting where the “Belle” variety was used as a scion, tomato yield decreased and they obtained higher yields than tomato plants without vaccine. However, Neocleous (2010) reported in his study that there was no difference in the total yield of grafted tomato plants.

Table 4. The effect of the number of different stems in grafted and non-grafted tomato on the amount of Brix^0 of the fruit juice (%)

Varieties	Grafted double stem	Non-grafted double stem	Grafted single stem	Non-grafted single stem	Average (Variety)
Android F_1	4.33	4.53	4.02	4.02	4.25
Torry F_1	4.38	4.40	3.93	4.25	4.24
Average (Grafting)	4.35 AB*	4.46 A	3.98 C	4.14 BC	
LSD %5	(Graft.): 0.24	(Var.): ns	(Graft. x Var.): ns		

*Means in the same line by the same letter are not significantly different ($P \leq 0.05$), ns: Non-significant.

Table 5. The effect of the different stem numbers in grafted and non-grafted tomatoes on the number of fruits in the cluster in the Android F_1 tomato variety (number of fruit cluster^{-1})

Cluster	Grafted double stem	Non-grafted double stem	Grafted single stem	Non-grafted single stem	Average (Cluster)
1	5.10	5.63	5.50	5.73	5.49 A*
2	5.18	5.08	5.13	5.48	5.21 A
3	4.13	3.90	4.55	3.78	4.09 B
4	3.88	3.73	4.60	3.75	3.99 B
5	3.13	4.10	3.55	3.93	3.68 B
6	0.80	1.48	1.60	2.28	1.54 C
Average (Grafting)	3.70 B**	3.98 AB	4.15 A	4.15 A	
LSD %5	(Graft.): 0.34	(Cluster): 0.42	(Graft x Cluster): ns		

*Means in the same column by the same letter are not significantly different ($P \leq 0.05$), ns:Non-significant, **Means in the same line by the same letter are not significantly different.

Table 6. The effect of the different stem numbers in grafted and non-grafted tomatoes on the number of fruits in the cluster in the Torry F_1 tomato variety (number of fruit cluster^{-1})

Cluster	Grafted double stem	Non-grafted double stem	Grafted single stem	Non-grafted single stem	Average (Cluster)
1	5.05	4.63	5.18	5.80	5.16 A*
2	5.13	5.00	4.95	5.10	5.04 A
3	3.78	3.80	3.70	3.95	4.10 B
4	4.03	4.28	3.90	4.18	3.80 BC
5	3.43	3.63	3.45	3.95	3.61 C
6	1.02	1.63	1.78	1.80	1.56 D
Average (Grafting)	3.74	3.83	3.83	4.13	
LSD %5	(Graft): ns	(Cluster): 0.37	(Graft. x Cluster): ns		

*Means in the same column by the same letter are not significantly different ($P \leq 0.05$), ns: Non-significant.

Table 7. The effect of different number of stems in grafted and non-grafted tomato on average fruit weight (g)

Varieties	Grafted double stem	Non-grafted double stem	Grafted single stem	Non-grafted single stem (control)	Average (Variety)
Android F_1	173.60	188.00	185.00	184.80	182.70
Torry F_1	182.30	163.10	190.00	174.30	177.40
Average (Grafting)	177.90	175.60	187.50	179.50	
LSD %5	(Graft): ns	(Var.): ns	(Graft. x Var.): ns		

ns: Non-significant.

Table 8. The effect of the different number of stems in grafted and non-grafted tomato on total yield (kg m^{-2})

Varieties	Grafted double stem	Non-grafted double stem	Grafted single stem	Non-grafted single stem	Average (Variety)
Android F_1	9.10 d	10.49 bc	12.11 a	12.67 a	11.10
Torry F_1	11.88 a*	9.72 cd	10.80 b	11.86 a	11.06
Average (Grafting)	10.49 C**	10.10 C	11.46 B	12.27 A	
LSD %5	(Graft): 0.67	(Var.): ns	(Graft x Var.): 0.95		

*Means in the interaction by the same letter are not significantly different ($P \leq 0.05$), ns: Non-significant, **Means in the same line by the same letter are not significantly different.

4. Conclusion

The effect of double stem in cotyledon axillary buds on yield in grafted tomato cultivation was found to be statistically significant, and different treatments decreased the yield. The highest yield was obtained from the control plants (12.27 kg m^{-2}), the lowest values in grafted and non-grafted double stem treatment were 10.49 kg m^{-2} and 10.10 kg m^{-2} respectively. According to the control, a decrease in the yield was determined to be 6.6% in grafted single-stem plants and 14.5% in grafted double-stem plants. By comparison, in double-stemmedtomatoes it is seen that the rootstock provides a 3.7% increase in yield. This decrease is due to the same amount of fertilizer value given to the unit area in grafted double stem plants.The small difference between grafted and non-grafted plants is related to the rootstock-scion compatibility, rootstock power and the amount of water and fertilizer given per unit area. Acomparision of "Android" and "Torry" varieties used in the study showed no difference between them in terms of yield. the double stems created by cotyledon axillary buds did not shown a homogeneous development in the greenhouse as expected, and a slight difference was observed in development between both branches. Differences of development in double branches has been seen not only in the grafted plants but also in non-grafted double stem plants. It is thought that the unbalanced development of double-stem plants is caused by the stress of pruning in seedlings to eliminate apical domination. In other words, it is predicted that the angle given to the top shoot in the seedlings and the height of the terminal shoot may make a difference in the development of the stems. In addition to the fact that rootstock and variety are important criteria in grafted tomato cultivation, the use of double laterals in fertilization and irrigation in double stem tomato cultivation is important and necessary in terms of irrigation and water demand, and the fertilization should remain higher in grafted plants with double stem for adequate yield. If the same fertilizer is given, compared to traditional planting in double stem cultivation, two drip lines should be drawn on both sides of the root collar of the plant, and in case of a single drip line, the fertilizer dose should be increased. According to the findings of this study, a double drip line without increasing the fertilizer dose would be a more appropriate choice.

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Phenological and pomological characterization of promising loquat (*Eriobotrya japonica*) cultivars suitable for the Mediterranean climate

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Yield

ABSTRACT

This study was conducted during the 2017 and 2018 growing seasons to determine the yield performances, phenological and pomological characteristics of ten 21-year-old loquat cultivars grown under Mediterranean conditions at Dörtyol, Hatay, Turkey. The flowering of the cultivars was observed in detail and the earliest flowering was found in 'Akko XIII' and the latest in 'Ottaviani' cultivars. Among the tested cultivars, the highest yield was found in 'Champion' (168 kg tree^{-1}, 387.36 g cm^{-2}) whereas the earliest and latest ripening cultivars were found as 'Akko XIII' and 'Lapta M', respectively. The highest values in terms of fruit weight, seed weight and seed number were obtained from 'Baduna 5' variety as 50.60 g, 9.59 g and 4.50 fruits, respectively. In terms of fruit flesh/seed ratio, 'Hafif Çukurgöbek' (5.33) had the highest value, while 'Lapta M' (3.29) had the lowest. The highest total soluble solids, pH and acidity values were measured in 'Hafif Çukurgöbek' (13.70%), 'Lapta B2' (3.85) and 'Lapta M' (1.15), respectively. The cultivars used in the study were compared using the Weighted-Rankit Method according to their important characteristics and the cultivar 'Hafif Cukurgöbek' got the highest score. However, the results showed that most of the cultivars used in the experiment, except 'Lapta M', could be grown economically in the Mediterranean climate.

1. Introduction

Loquat (*Eriobotrya japonica* (Thunb.) Lindl) is an evergreen subtropical fruit, which unlike most fruit trees, blooms in autumn and winter. As it blooms in autumn and winter, pollination, fertilization, and therefore yield can be adversely affected (Eti et al. 1990). When the ecological conditions are taken into account, it can be easily grown in the coastal areas of the Mediterranean Region and some regions of Turkey with microclimate characteristics. (Polat 1996). However, almost all of the loquat cultivation in Turkey is carried out in the Mediterranean Region (Çelikyurt et al. 2011; Tepe 2013).

Considering the climatic conditions and location in the Mediterranean region, Hatay should be in a much better situation than other provinces but unfortunately has lagged behind in terms of the number of loquat trees and the amount of production. Achieving early ripening in the period when fresh fruits are limited in the market, could provide a satisfactory income for the producers (Durgac et al. 2006). In addition, Hatay, being very close to the Middle Eastern countries, has an advantage of marketing loquat in both domestic and foreign markets (Kızıl 2019).

This study aimed to determine the most suitable loquat varieties for the Dörtyol region, which is under the influence of the Mediterranean climate, and thus to contribute to loquat cultivation both in our country and in other countries with similar ecologies.

2. Materials and Methods

The study was carried out on 21-year-old loquat plants planted at a distance of 6x6 m in Dörtyol (Hatay), located in the Mediterranean climate zone, in the 2016-2017 and 2017-2018 vegetation periods. The vegetative growth, yield, phenological and pomological characteristics of the cultivars ('Akko XIII', 'Baduna 5', 'Gold Nugget', 'Güzelyurt 1', 'Hafif Çukurgöbek', 'Lapta B2', 'Lapta M', 'Ottaviani', 'Sayda' and 'Champion') were determined through the methods outlined below with five replications.

Phenological observations were made in detail from the beginning of flowering to the ripening period. The results were evaluated according to Durgac et al (2006) i.e. the period in which 5% of the flowers blossomed was assumed to be "beginning of blossoming", the period in which 70% of the flowers blossomed was assumed to be "full bloom", and the period in which the flowers drop 70% of their petals after pollination was assumed to be "end of blossoming". The first stage in which the receptacle swells and turns into fruit after the flowers have dropped their petals was assumed to be "fruit set", and after that, the stage in which the formed fruits reach the size of a hazelnut was assumed to be "small fruit". The fruits were harvested in the period in which cultivars obtain their specific properties such as color and taste.

To determine the relationship between vegetative growths and yield components, the trunk circumference of the trees were measured 10 cm above from the grafting point using a tape measure. With the help of the values obtained, the cross-sectional areas were calculated. After determining the tree yield (kg tree^{-1}), the yields per unit trunk cross-sectional area (g cm^{-2}) were calculated.

Within the scope of the pomological analysis, 50 fruit samples were picked randomly as five replications, which each tree being one replication (10 fruits per tree), at harvest time (the period when 70% of the fruits mature). Pomological characteristics of these fruit samples such as fruit weight, fruit width, fruit length, width/length index, number of seeds, seed weight, flesh/seed ratio, fruit skin color, fruit flesh color, total soluble solids (TSS), pH and titratable acidity were determined.

The experiment was planned as five replications, with one plant per replicate. The data were analyzed by ANOVA with a completely randomized design and the mean comparison with the 'Duncan Test' (Steel and Torrie 1980). Statistical analyses of the obtained data were performed using the SPSS Statistics program. The data obtained at the end of all these calculations were evaluated using the 'Weighted-Rankit Method' (Yazgan 1979), taking into account the most desired features in loquats.

3. Results and Discussion

3.1. Phenological observations

According to the phenological observations, flowering periods of the cultivars took place between 2 November 2017 and 25 February 2018 (Fig. 1). 'Akko XIII' was the earliest and 'Ottaviani' was the latest blooming cultivar. Due to the characteristics of the varieties and the effect of ecological conditions, some annual differences were observed in the flowering period of plants. Akkuş and Polat (2022) found the flowering period of the 'Hafif Çukurgöbek' cultivar between 11 December and 31 January in Antakya. The same cultivar flowered between 26 November 2017 and 22 January 2018 in our study. The flowering of 'Hafif Çukurgöbek' cultivar started and ended earlier in our study. This difference is probably due to the fact that the study site location was very close to the sea, while the study site of Akkuş and Polat (2022) was approximately 30 km further away from the sea. Polat and Çalışkan (2011a) found the flowering period between November 14 and February 17 in a previous study on the same field and on the same plants as in this study. Durgac et al. (2006) found the flowering period between 26 November and 3 February. Our findings were similar to those of Polat and Çalışkan (2011a), and differed from those of Durgac et al. (2006) and Akkuş and Polat (2022). The longest blooming period was found in 'Sayda' (36 days), the shortest in 'Ottaviani', 'Hafif Çukurgöbek' and 'Baduna 5' (17 days each). The observations in our study generally coincide with the observations made by Polat and Çalışkan (2011a).

As with many other fruit species, early maturing cultivars in loquats are usually sold at a higher price than mid-season ripening cultivars. For this reason, precocity is an important criterion in terms of marketing. In terms of precocity, 'Akko XIII' was the earliest to mature. This was followed by 'Hafif Çukurgöbek' and 'Champion' varieties, respectively. The latest maturing variety was 'Lapta M'. The first harvest of all varieties was between mid-April-early May, and the last harvest was between the end of May-early June. Previous studies under Hatay ecological conditions have shown that the average harvesting period was between mid of May and mid of June (Durgac et al. 2006; Polat and Çalışkan 2011a). These small differences between studies may be due to cultural practice conditions and climatic parameters that change over the years.

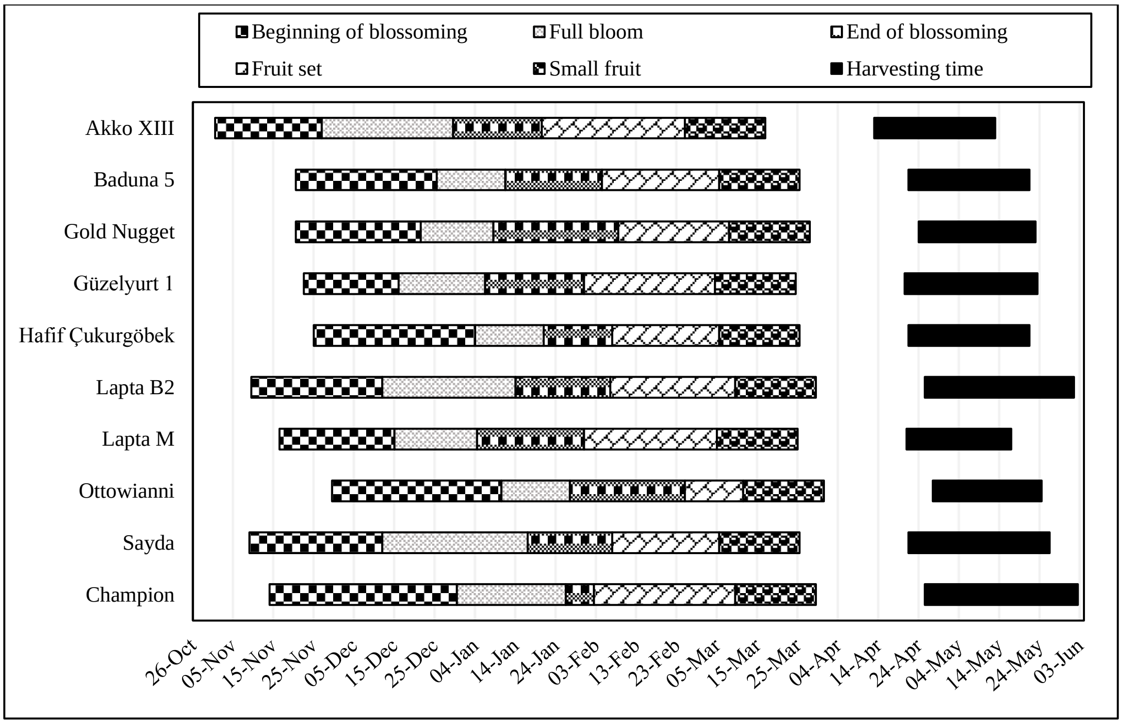

Figure 1. Phenological observations of cultivars (average of years 2017–2018).

3.2. Yield components

The differences in yield per tree and per unit trunk cross-sectional area of the cultivars were statistically significant ($P \leq 0.05$) (Table 1). In the study, yields per tree and per unit trunk cross-sectional area were found to be between 50.02-168.46 kg $tree^{-1}$ and 96.94-387.36 g cm^{-2}, respectively. The highest yield per tree and unit trunk cross-sectional area was obtained from 'Champion' and the lowest yield was obtained from 'Lapta M' cultivars. In a previous study, the highest yield per tree from the 'Champion' cultivar with 56.80 kg $tree^{-1}$, and the lowest from 9.30 kg $tree^{-1}$ from the 'Lapta 1' cultivar were reported (Polat and Çalışkan 2011a), respectively. In terms of yield per unit trunk cross-sectional area of 'Gold Nugget' cultivar, Razeto et al. (2003) found between 0.12 kg cm^{-2} and 0.64 kg cm^{-2}, and Durgac et al. (2006) obtained 44.15 g cm^{-2}. The yield values obtained in our study were found to be higher than those of Polat and Çalışkan (2011a) and Durgac et al. (2006) and close to the yield values of Razeto et al (2003). This difference between the studies may have resulted from both the age of the plants and cultural processes. The results in our study were obtained from 21-year-old trees, whereas Durgac et al. (2006) were obtained from 6-year-old trees.

Table 1. Yield parameters of cultivars (average of years 2017–2018)

Cultivars	kg $tree^{-1}$	g cm^{-2}
Akko XIII	143.00 ab*	297.39 b
Baduna 5	118.16 bcd	288.83 b
Gold Nugget	84.29 e	268.53 bc
Güzelyurt 1	128.69 bc	291.88 b
Hafif Çukurgöbek	104.39 cde	285.57 b
Lapta M	50.02 f	96.94 d
Lapta B2	133.13 bc	290.67 b
Ottaviani	143.74 ab	272.30 bc
Sayda	89.80 de	197.43 c
Champion	168.46 a	387.36 a

*Values in the same column with different letters are significantly different ($P \leq 0.05$).

3.3. Pomological analyses

The pomological analyses of loquat cultivars are depicted in Table 2. There were statistical differences ($P \leq 0.05$) among all the pomological characteristics of the cultivars. Fruit size, which varies due to genetics and environmental conditions (such as the age of the tree, the amount of fruit set and cultural practices), is an important factor in loquat marketing. Fruit weights of the cultivars ranged from 24.85 g ('Lapta M') to 50.60 g ('Baduna 5'). Previous studies reported that the highest fruit weight was found in 'Guzelyurt 1' with 37.80 g, and the lowest fruit weight was found in 'Akko XIII' with 20.20 g (Polat and Çalışkan 2011a). The average fruit weights reported in other studies, 50 g for 'Mogi', 60 g for 'Nakasakiwase' and 70 g for 'Tananka' in Japan; 70 g for 'Jiefangzhong', 60 g for 'Dawuxing' and 'Zaozhong No-6', in China; 65g for 'Algerie' in Spain (Lin et al. 1999). Llácer et al. (2003) reported that the average fruit weight of 'Ullera' cultivar is 90 g in Spain and this cultivar can produce fruit up to 250 g. Compared to the above studies, fruit size of our cultivars in the experiment was relatively small. In another study conducted in Adana, fruit weights of the cultivars ranged from 22.47 g ('Champagne de Grasse') to 39.14 g ('Dr. Trabut') (Paydaş et al. 1992). The fruit weights obtained in our study were found to be higher than similar cultivars used in both studies. The relationship between varieties in terms of fruit sizes (width, length) was found to be similar to fruit weight.

Caldeira and Crane (1999) reported that the fruit shape of loquats varied from pear shape to round generally. When the fruit index value (width/length) approaches 1.00, it is considered to be round. In our study, the width/length ratios of the loquat cultivars ranged from 0.92 to 0.81. These results showed similarities with the results of Polat et al. (2003) and Uzun et al. (2012) who reported 0.90-0.80 and 0.88 and 0.76, respectively.

When the seed weight and number of the experimental cultivars were considered, the highest values were found in 'Baduna 5' (9.59 g and 4.50 pieces $fruit^{-1}$) while the lowest seed weight (4.85 g) was found in 'Champion' and the lowest seed number (2.99 pieces $fruit^{-1}$) was found in 'Gold Nugget' cultivars. Özdemir and Topuz (1997) found the highest seed weight in 'Gold Nugget' cultivar with 3.22 g, and the lowest seed weight in 'Tanaka' cultivar with 0.73 g in a study they conducted in Antalya. The researchers determined the maximum number of seeds (3.30 pieces $fruit^{-1}$) in the 'Hafif Çukurgöbek' and the least (1.75 pieces $fruit^{-1}$) in the 'Seedling'.

As in many other fruit species, the fruit flesh/seed ratio is another important fruit quality factor in loquats. Flesh/seed ratio was highest in 'Hafif Çukurgöbek' (5.33), and lowest in 'Lapta M' (3.29). In different studies, flesh/seed ratio values of the loquat cultivars changed between the highest 6.03 and the lowest 3.42 (Erdogdu 1987; Yalcin and Paydaş 1995; Yilmaz et al. 1995; Polat et al. 2003; Tepe and Koyuncu 2020).

Table 2. Average pomological analyses of loquat (*Eriobotrya japonica* (Thunb.) Lindl) cultivars between 2017 and 2018

Cultivars	Fruit weight (g)	Fruit width (mm)	Fruit length (mm)	Width/length index	Seed weight (g)	Seed number (piece)	Flesh/seed ratio	Fruit skin color	Flesh color
Akko XIII	41.30 bc*	39.95 b	43.21 c	0.92 a	7.09 bc	3.69 b	4.78 abc	Orange	Orange
Baduna 5	50.60 a	42.34 a	50.63 a	0.84 cd	9.59 a	4.50 a	4.29 bc	Yellow	Cream
Gold Nugget	32.60 de	37.61 cd	42.56 c	0.88 abc	5.45 de	2.99 c	5.00 ab	Orange	Orange
Güzelyurt 1	44.49 bc	40.21 ab	48.07 b	0.84 cd	7.95 bc	3.64 b	4.62 abc	Yellow	Cream
Hafif Çukurgöbek	36.25 cd	39.19 bc	43.66 c	0.90 abc	5.81 de	3.32 bc	5.33 a	Orange	Orange
Lapta B2	31.87 de	36.61 de	42.96 c	0.85 bcd	6.04 de	3.42 bc	4.36 bc	Yellow	Cream
Lapta M	24.85 f	34.42 ef	39.44 d	0.87 bc	5.80 de	3.06 c	3.29 d	Yellow	Cream
Ottaviani	42.08 bc	40.50 ab	47.59 b	0.85 bcd	7.00 c	3.82 b	5.02 ab	Orange	Orange
Sayda	27.41 ef	34.55 ef	42.79 c	0.81 d	5.61 de	3.44 bc	4.05 c	Orange	Orange
Champion	26.80 ef	32.84 f	40.52 d	0.81 d	4.85 e	3.25 bc	4.65 abc	Yellow	Cream

*Values in the same column with different letters are significantly different by Duncan's test ($P \leq 0.05$).

The fruit skin colors of the cultivars were divided into two groups as orange and yellow. 'Akko XIII', 'Gold Nugget', Hafif Çukurgöbek', 'Ottaviani' and 'Sayda' cultivars were found to have orange fruit skin color, 'Baduna 5', 'Güzelyurt 1', 'Lapta M', 'Lapta B2' and 'Champion' cultivars had yellow fruit skin color. The flesh color of the cultivars with orange fruit skin color was also orange, while the fruit flesh color of the cultivars with yellow fruit skin color was determined as cream. The results of our study are similar to other studies (Paydaş et al. 1991; Durgac et al. 2006; Ferreres et al. 2009; Polat and Çalışkan 2011a; Tepe 2013; Balcı 2015; Tepe and Koyuncu 2020; Dhiman et al. 2021).

The total soluble solids contents of the loquat cultivars vary from 7 to 20% (Lin et al. 2007). In general, a high-quality loquat fruit has high Total Soluble Solids (TSS) content. In our study, TSS content was found to be over 11.5% in all loquat varieties except 'Ottaviani' and 'Gold Nugget'. 'Hafif Çukurgöbek' (13.70%) and 'Lapta B2' (13.68%) cultivars were found to have the highest TSS content, and 'Ottaviani' (9.82%) the lowest. In different studies, 'Gold Nugget' had 11.2 % in Italy (Insero et al. 2003), and 11.2% TSS content in Spain (Llácer et al. 2003). While pH values varied between 3.85 and 3.42, the highest and lowest values were obtained from 'Lapta B2' and 'Lapta M' cultivars, respectively. Malic acid is the predominant organic acid in loquats. It confers a tart taste to fruit, although the amount decreases with increasing fruit ripeness (Gurtler and Mai 2014). Acidity of the cultivars varied between 0.42% ('Güzelyurt 1') and 1.15% ('Lapta M'). There is generally an inverse relationship between the pH value of the fruits and their acidity. The acidity was low in cultivars with high pH value and high acidity was found in cultivars with low pH value (Figure 2).

3.4. "Weighed Rankit Method" of the cultivars

All the cultivars in the study were evaluated with the "Weighed Rankit Method", and the scores obtained from each characteristic of the cultivars and their total scores are given in Table 3. The "Weighed Rankit Method" score was highest in 'Hafif Çukurgöbek' (800 points) and lowest in 'Lapta M' (450 points). It is thought that not only 'Hafif Çukurgöbek' but also 'Akko XIII', 'Champion' and 'Güzelyurt 1' varieties with a score above 700 can be successfully grown in the Mediterranean climate.

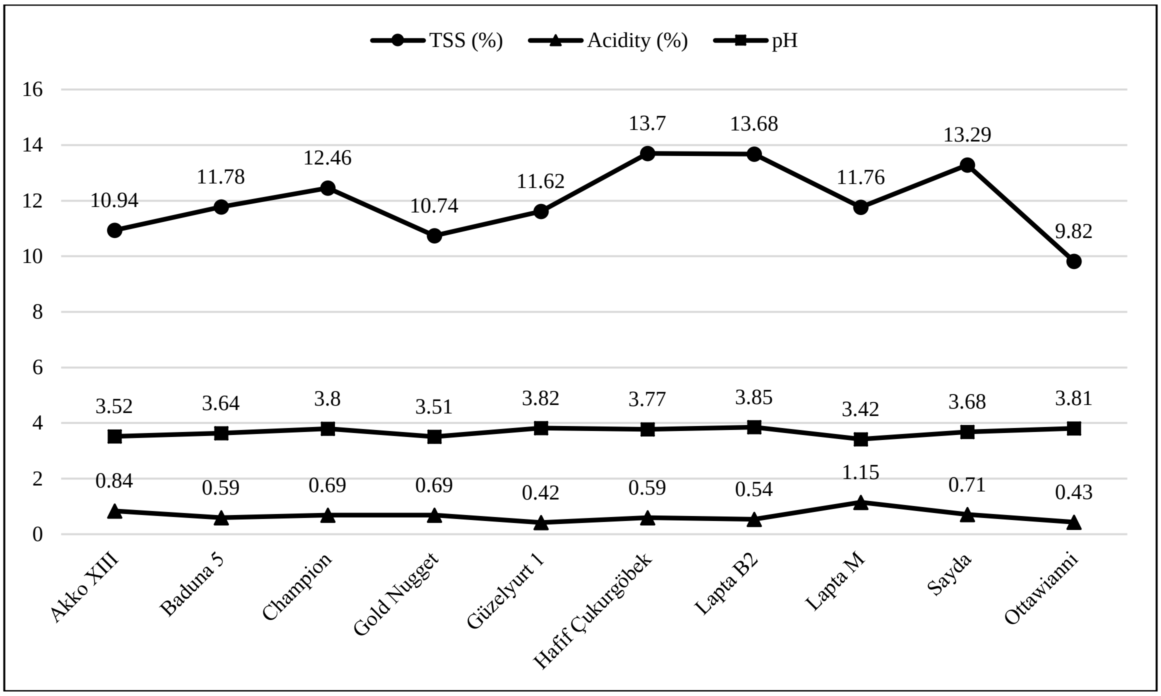

Figure 2. Total soluble Solids (TSS), pH and titratable acidity contents of loquat cultivars.

Table 3. Weighted-Rankit Method scores of the cultivars for some important commercial characteristics

Cultivar	Yield (Kg tree^{-1})	Fruit weight (g)	Seed number (piece)	TSS (Brix)	Flesh/seed ratio	Fruit skin color	Precocity	Total
Akko XIII	200	160	60	60	80	100	100	760
Baduna 5	150	200	40	90	60	50	40	630
Gold Nugget	100	120	100	60	80	100	80	640
Güzelyurt 1	200	160	60	90	80	50	60	700
Hafif Çukurgöbek	150	120	80	150	100	100	100	800
Lapta B2	200	40	80	150	60	50	80	660
Lapta M	50	120	80	90	20	50	40	450
Ottaviani	200	160	60	30	100	100	40	690
Sayda	100	80	80	150	60	100	80	650
Champion	250	80	80	120	80	50	100	760

4. Conclusions

The loquat is one of the most important species in minor fruit trees in Mediterranean countries. Under Mediterranean climatic conditions loquats bloom in autumn and winter, and fruits ripen mostly in spring. During this period, they are sold at high prices, as there are few competitive fruits on the market except for strawberry, green plum, and green almond. In addition, due to the limited loquat cultivation in the world, it can be sold at high prices in international markets. In our study, 'Akko XIII' was most suitable for its fruitfulness; 'Champion' for its productivity; 'Baduna 5' for its large fruits; 'Hafif Çukurgöbek' for its flesh/seed ratio, TSS and bright orange color. Our results revealed that all cultivars except 'Lapta M' were promising in terms of yield, plus various pomological and phenological characteristics. Nevertheless, 'Hafif Çukurgöbek' cultivar comes to the fore in the common expectations (fruit quality, suitability for transportation, attractiveness) of both producers and consumers.

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Appendix

The cultivars used in the experiment and their characteristics are given below.

'Akko XIII' is an attractive and delicious cultivar with dark pink fruits that ripen in mid-season. It is very resistant to transportation and Black Spot disease. TSS content and malic acid content are 25-40 g, 10-11% and 1-1.7%, respectively (Demir 1987; Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Gold Nugget' is a dark orange, attractive, delicious and late maturing loquat cultivar originating from the USA, with an average fruit weight of 35-40 g. It is a self-fertile cultivar and begins to bloom in mid-November. TSS content is around 11-12% and pH value is between 3-3.5 (Demir 1987; Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Güzelyurt 1' is a Cyprus origin cultivar and is sensitive to cold. It starts to bloom from the beginning of December and at the end of the same month, almost all of the flowers bloom. Fruit weight is around 40-45 g and seed weight is between 2-3 g (Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Hafif Çukurgöbek' is an early maturing cultivar selected from Turkey. Its fruits are pink-orange, attractive, very tasty and sweet. It is a variety that is partially suitable for transportation, resistant to black spot disease and self-fertile. Average fruit weight, TSS content, pH value and malic acid content are between 45-50 g, 12-13%, 3-3.5 and 0.9-1%, respectively (Demir 1987; Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Lapta B2' is a Cyprus origin cultivar and its flowering period continues from the beginning of December to the end of January. The average weight of the fruits is 30 g and usually contains 2-3 seeds. TSS content of its fruits is between 12-13%, pH value is 3.5-4, malic acid content is between 0.4-0.5 (Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Lapta M' is a Cyprus origin cultivar and is sensitive to winter cold. It begins to bloom at the end of November and ends in the second half of January. The number of seeds in the fruits is generally low and the TSS content is 13-14% (Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Ottaviani' is a delicious mid-season loquat cultivar with very large pear-shaped fruits. It is resistant to black spot diseases. Average fruit weight is 40-41 g, pH value is 3.5-4, TSS content is 8-9%, and malic acid content is around 0.4-0.5% (Demir 1987, Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Sayda' is an early maturing cultivar with large, pink-orange colored, very sweet and delicious fruits. It is moderately resistant to transport and black spot disease. Average fruit weight is 32 g, TSS content is 13-14%, pH value is between 3-3.5, malic acid ratio is between 1-1.5% (Polat and Çalışkan 2011b; Polat and Turunç 2015).

'Champion' begins to bloom from the end of November and continues to bloom until the beginning of January. Average fruit weight is 33-34 g, TSS content is 12%, pH is 3.5-4, malic acid ratio is between 0.6-0.7%. (Polat and Çalışkan 2011b; Polat and Turunç 2015; Karabıyık and Eti 2015).

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Insect species and their abundance in sunflower and soybean seeds in warehouses in the Çukurova Region, Türkiye

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ABSTRACT

Harmful insect species were investigated in soybean and sunflower seed samples mixed with weed seeds and stored for a short time in the open field in the Çukurova Region (Türkiye) including Adana, Mersin and Osmaniye Provinces in 2020. A total of 8 harmful insect species were found in the samples of stored soybean and sunflower seeds. Seeds of 12 weed species were detected in both soybean and sunflower seed samples. The red flour beetle, *Tribolium castaneum* (Herbsts, 1797) (Coleoptera: Tenebrionidae) was the major pest insect in both sunflower and soybean seeds. A few species of the rice weevil, *Sitophilus oryzae* (L. 1763) (Coleoptera: Curculionidae), which are the primary pest of stored cereals, were recorded under outdoor conditions. No insect feeding damage was observed on the seeds of both crops and also on the seeds of the weeds. Finally, the seeds of soybean and sunflower crops which were harvested and kept outside the warehouses, for a short time, were attacked by some stored pest insects particularly *Tribolium* spp. This issue may create a problem, in the case that harvested crops with insects are moved into the warehouse,which has suitable temperature and moisture for the pest insects to develop and multiply.

1. Introduction

Sunflower is one of the first plants that comes to mind when it comes to oilseeds in Türkiye, and it is grown for oil and snack foods. Sunflower meets 50% of the crude vegetable oil production in Türkiye (Semerci and Durmuş 2021). Although the amount of production has decreased slightly compared to the previous year, it has increased exponentially in the last 30 years (FAO 2021). The provinces where sunflower production is intense in Turkey are: Tekirdağ, Konya, Edirne, Kırklareli and Adana, these provinces meet 68% of the total production, and 2067004 tons of sunflower was produced in Türkiye in 2020 (Semerci and Durmuş 2021). Oil sunflower production reached 2.3 million tons in 2022. Total sunflower production was announced as 2.55 million tons. The estimation of the Turkish Statistical Institute for 2021, with an increase of 5.29 percent compared to the previous year (TÜIK 2022). The following are considered oilseed plants on a global scale; Soybean, sunflower, peanut, rapeseed, sesame, safflower, olive, maize, palm seed, coconut, oil flax and castor oil plants. When production amounts are taken into account, soybean, rapeseed, sunflower, peanut, cottonseed and palm kernel crops come first.

Soybean seeds contain 18-24% oil, 35-40% protein, and provide organic matter and nitrogen to the soil (Uçum and Korkut 2019). Soybean is the plant with the highest cultivation area and production amount among oilseed plants in the world. While oilseed production was carried out on 277 million hectares of land in the world in the 2017-2018 season, soybean production was carried out on 124 hectares of these areas and this accounted for 45% of the total oilseed cultivated areas. As of the 2017-2018 season, the total oilseed production in the world was 573 million 620 thousand tons, while soybean production was 336 million 820 thousand tons. Worldwide, the share of soybean production in the total production of oilseed plants was 61.1% (Uçum and Korkut 2019). In the 2018/19 season, soybean production in Türkiye reached 140 thousand tons, harvested from 328 thousand decares of land. In 2022, soybean production expanded to 2.415 tons. During this season, Adana Province accounted for approximately 64% of soybean production areas, while Mersin Province accounted for 28% (TUİK 2022).

Sunflower and soybean production statistics indicate that these two plant species contribute significantly to meeting the oil needs of Türkiyeand the world. As with other harvested oilseed crops, sunflower and soybean seeds are stored and evaluated in the market at the most appropriate time. Studies have been carried out on pest insects/mite species and their importance in mainly stored grains in Türkiye (Ekecan and Özgür 1990; Çankaya 1998; Mert 2012; Aydın 2011; Bağcı et al. 2014; Işıkber 2005; Işıkber et al. 2016; Özgen et al. 2018; Sekrane et al. 2022). Information about harmful arthropoda species in stored oilseeds is not clearly understood. However, in the review by Rajendran and Chavadevi (2004); 13 insect species were recorded in stored soybean seeds and 6 insect species in sunflower seeds, the most important among them: *Tribolium* spp. (Coleoptera: Tenebrionidae) and, together with *Ephestia cautella* (Walker, 1863) *Plodia interpunctella* (Hubner, 1813) (Lepidoptera: Pyralidae). White et al. (2011) reported that *Cryptolestes ferrugineus* (Stephens, 1831) (Coleoptera: Cucujidae) and

Tribolium castaneum (Herbsts, 1797) (Coleoptera: Tenebrionidae) species were quite common, especially in oilseeds and grains in the heated warehouses in Canada, and the cold tolerance of *Sitophilus granarius* (L. 1875) (Coleoptera: Curculionidae) and *P. interpunctella* were higher than the other two species.

Products intended for storage, including grains, legumes, and oilseeds, should be inspected to ensure that they are free from foreign objects and weed seeds. In the case of products that are contaminated with weed seeds, the moisture content can be high, creating ideal conditions for primary or secondary pests to proliferate quickly during storage (Rees 2004). For this purpose, the possible effects of crop seeds contaminated with weed seeds, stored for a short time on the abundance of insect species (number of individuals) was investigated in this study.

In stored products, harmful insects are generally the primary pests that directly damage the healthy grains and their larvae and/or adults mostly feed on the core (embryo) part of the grains. The secondary pests that feed on the grains that are destroyed by the feedings of the primary pest or for various reasons cause damage (Özgür 1984; Rees 2004). Studies with harmful insect species in stored products around the world have been carried out after the product is stored for a short or long term. While the main habitat of harmful insects in stored products is storage (eg *S. granarius*), some of them can live both outdoors and in warehouses (eg *Tribolium* spp.). In other words, such insects are transported to the warehouse with the products, multiply under suitable conditions and become harmful (Rees 2004). No study has been found yet of harmful insects or mite species in stored oilseeds in Türkiye. Before the product is put into storage, it is important to know whether the product has insects or mites and also weed seeds. In this study, insect species and their densities were investigated in sunflower and soybean seeds samples containing weed seeds and kept for a short time in the open field before being taken into the warehouses after post harvest.

2. Materials and methods

2.1. Samplings

Sunflower seeds samples were taken from bulk heaps, which were kept in the open area for about 10-15 days, between 21 July, and 28 August, 2020, before the harvest crops were stored (i.e seeds of both crops) in the warehouses or reinforced concrete horizontal warehouses in Çukurova Region, Türkiye. Sunflower seed heaps have a capacity of about 17 tons. Samples were taken from Ceyhan (38), Karaisalı (1), Sarıçam districts (9) in Adana Province; Kadirli district of Osmaniye (6); Tarsus district of Mersin Province (19). A total of 73 samples were obtained from 26 warehouses located in Adana (18), Mersin (5), and Osmaniye (3) for analysis in this study. The moisture content of the sunflower seeds varied between 8 and 10.5%. Soybean samples were taken from bulk piles, which were kept in the open area for about 10-15 days before the product was taken into the warehouses between September 15 and October 20 in 2020, similar to the collections of sunflower samples. Seeds of various soybean cultivars, including Arısoy, Asya, Lider, MonaSandoz 4240Blaze, AG3546, Planet, and Sonya, were collected and stored separately prior to analysis. The bulk capacities are on average 25 tons. Product grain moisture ranged from 12 to 14%. Soybean seed samples were taken from 19 warehouses from Adana, 8 from Mersin and 8 from Osmaniye, Ceyhan (8), Seyhan (14), Karataş (12), Yüregir (7), Kozan (9) Sarıçam (1); Osmaniye Province Kadirli district (15) and Mersin Province Tarsus district (34). Each soybean or sunflower sample (seeds) was taken randomly from the upper, middle and lower parts to represent the crop heap, with a total of 1 kg. A total of 100 samples were evaluated for identifications of the weed seeds and pest insects of the stored products.

2.2. Detection of seeds of weed species in sunflower and soybean seed samples

The samples were brought to the Weed Science Laboratory, Department of Plant Protection, Çukurova University, and then the crop seeds, i.e. soybean and sunflower seeds, and weed seeds were separated by eye under a large table magnifier with LED light using forceps and spatulas. The separated weed seeds were compared with the seed samples from the seed collection in the herbarium under the DMSZ7P stereo-binocular microscope with aninternal camera, and the same ones were grouped together.

Weed seeds were identified by comparison with the previously identified weed seeds, and also by using different identification keys (Hanf 1990; Meyer and Effenberger 2010; Parkinson et al. 2013; Uygur et al. 2020; ISMA 2022). However, those whose identifications were unclear, were germinated in the growing cabinets and their development was followed until the fruiting period.

2.3. Detection of insects from sunflower and soybean seed samples

During the analysis of sunflower and soybean samples containing weed seeds, the weed seeds were sorted and counted by species, for each 1 kg sample. Each sunflower or soybean sample was first evaluated in terms of weed seeds, and the sample was taken back into the same polyethylene plastic bags without deteriorating its properties. The bags were again examined in terms of harmful/beneficial insects in the entomology laboratory in the same department. For this purpose, the samples were passed through a 10 mesh sieve, and the insect samples falling under the sieve were collected with the help of a wet-tipped No. 2 fine brush and stored in plastic tubes (1.8 cc) containing 70% ethyl alcohol for later evaluations of the collected specimens. Specimens were recorded by counting at the species level under the stereo-binocular microscope. Mostly adults of insect species were recorded from the samples. A few larvae belonging to the genus *Tribolium* were also found. Harmful mites and also beneficial insect/mite individuals could not be detected in the stored products.

The identification of the adult insects found in the sunflower and soybean seed samples was carried out by comparing them with the previously identified insect species stored in the Entomology Laboratory of the Plant Protection Department at the Faculty of Agriculture in Çukurova University. In addition, Özgür (1984)'s lecture note (Practical Identification Key) and the identification key of harmful insects in stored products published by Rees (2004) were used for the identification of insects under the stereo-binocular microscope with X 45 magnifications. Insect identifications at species level were carried out by the senior author.

2.4. Evaluation of data

Within the goal of this current study, weed seeds were identified at the species level and their densities were not evaluated. In addition, no insect damage was observed in weed seeds in each sample material. Insect species and densities in sunflower and soybean samples mixed with the weed seeds were recorded in the Excel file. Samples (different sunflower and soybean samples) taken from different or the same warehouses from each region on different dates were not evaluated at the variety level. The individual numbers of the insect species collected at different dates were combined and the total number of individuals and also the frequency of occurrence (%) of the species according to the region (districts) were given. By combining regions and warehouses and varieties (sunflower and soybean) sampling dates, the percentages of insect species in total adult individuals were tabulated separately according to sunflower and soybean products. The proportion (%) of a species in adult individuals was found by dividing the number of that species in the total population by the total number of adult population and multiplying by the constant of 100 according to (Karman 1971). In the sunflower and soybean samples taken from the crops harvested and stored in the open area for a short time in heaps, damage rates (%) were not given, since there was no insect damage to the grains.

3. Results and Discussion

3.1. Weed species in sunflower and soybean seed samples

The main or potentially harmful weed species, mixed with the sunflower or soybean seed samples are given in Table 1. In the study, a total of 49 weed species in sunflower seed samples, and 25 weed species in soybean seed samples were found during the harvest in the sampling locations. The most common weed species mixed with the soybean seeds were jute (*Corchorus olitorius*), redroot pigweed (*Amaranthus retroflexus*), field muskmelon (*Cucumis melo* var. *agrestis*). Along with sunflower seeds, lamb's-quarters (*Chenepodium album*), johnson grass (*Sorghum halepense*), redroot pigweed (*Amaranthus retroflexus*) were found extensively.

3.2. Insect species in sunflower and soybean seed samples

A total of 8 harmful insect species were found in the samples of stored soybean seeds, these are: *Lasioderma serricorne* (Fabricius, 1792) (Coleoptera: Anobiidae), *Sitophilus oryzae* (L. 1763) (Coleoptera: Curculionidae), *Cryptolestes turcicus* (Grouvelle, 1876) (Coleoptera: Laemophloeidae), *Carpophilus dimidiatus* (Fabricius, 1792) (Coleoptera: Nitidulidae), *Oryzaephilus surinamensis* (L. 1758) Coleoptera: Silvanidae), *Tribolium castaneum* (Herbsts, 1797) and *Tribolium confusum* Jacquelin du Val, 1863 (Coleoptera: Tenebrionidae) and *Liposcelis entomophila* (Enderlein, 1907) (Psocoptera: Lipocelidae) (Table 2). The most common (57%) species in the soybean seed samples and the highest prevalence (47.01%) in total adults was *T. castaneum*. This species was followed by *O. surinamensis* with a rate of 49% in samples and 28.80% in total individuals. Both species are polyphagous secondary pests of cereals and feed on many stored products. *Sitophilus oryzae*, which is the primary pest of cereals, was found in very low numbers in the samples, and it occurred rarely. The frequency of the other insect species in the samples and their rate in the total individuals were quite low.

Table 1. Weed species and their presence in sunflower and soybean seed samples in 2020

Family	Weed species	Sunflower	Soybean
Amaranthaceae	Redroot pigweed (*Amaranthus retroflexus* L.)	-[(a)]	+
	Lamb's-quarters (*Chenopodium album* L.)	-	+
Apiaceae	Wild carrot (*Daucus carota* L.)	+	
Asteraceae	Yellow starthistle (*Centaurea solstitialis* L.)	+	-
	Common cocklebur (*Xanthium strumarium* L.)	+	+
Boraginaceae	Common heliotrope (*Heliotropium europaeum* L.)	+	-
Brassicaceae	Wild radish (*Raphanus raphanistrum* L.)	+	-
	Wild mustard (*Sinapis arvensis* L.)	+	-
Convolvulaceae	Field bindweed (*Convolvulus arvensis* L.)	+	-
	Morning glory species (*Ipomoea hederacea* (L.) Jacquin, *Ipomoea triloba* L.)	-	+
Cucurbitaceae	Field muskmelon (*Cucumis melo* var. *agrestis* Naudin.)	-	+
Cyperaceae	Purple nutsedge (*Cyperus rotundus* L.)	-	+
Euphorbiaceae	Nodding spurge (*Euphorbia nutans* Lag.)	+	
Malvaceae	Jute (*Corchorus olitorius* L.)	+	+
	Venice mallow (*Hibiscus trionum* L.)	+	+
Poaceae	Sterile wild oat (*Avena sterilis* L.)	+	
	Barnyardgrass species (*Echinochloa colona* (L.) Link, *Echinochloa crus-galli* (L.) P. Beauv.)	-	+
	Common barley (*Hordeum vulgare* L.)	+	
	Johnson grass (*Sorghum halepense* (L.) Pers.)	-	+
Portulacaceae	Common purslane (*Portulaca oleracea* L.)	-	+
Solanaceae	Black nightshade (*Solanum nigrum* L.)	-	+

[a](-): not found, (+): found.

Table 2. Sample number of insect species found in soybean seeds, number of adults, and percentages of species in total adults in 2020

Insect species	Number of samples found	Frequency (%) in samples	No of individuals	Percentage of adults
Coleoptera				
Anobiidae				
Lasioderma serricorne	3	3	6	1.63
Curculionidae				
Sitophilus oryzae	3	3	4	1.08
Laemophloeidae				
Cryptolestes turcicus	3	3	3	0.82
Nitidulidae				
Carpophilus dimidiatus	35	35	72	19.56
Silvanidae				
Oryzaephilus surinamensis	49	49	106	28.80
Tenebrionidae				
Tribolium castaneum	57	57	173	47.01
Tribolium confusum	3	3	3	0.82
Psocoptera				
Lipocelidae				
Liposcelis entomophila	1	1	1	0.28

Similar to the soybean samples, a total of 8 insect species were recorded in the sunflower samples (Table 3). The same species were found in sunflower seeds, with the exception of *L. serricorne*. *Rhyzopertha dominica* (F., 1792) (Coleoptera: Bostrychidae) was detected in the sunflower samples in Table 3. Similar to the soybean samples, the most common (67%) in total adults and most abundant (621 individuals) insect species in the sunflower samples was *T. castaneum*. Unlike soybean samples, *T. confusum* was collected in relatively higher numbers (50 individuals) in the sunflower samples, constituting 6.03% of the total individuals, compared to its numbers found in the soybean samples. *Liposcelis entomophila* individuals were also noted in the sunflower samples, with a rate of 8.20% in total adults.

3.3. Abundance of insect species in samples of soybeans and sunflowers by districts

The total number of individuals belonging to different insect species according to districts level in sunflower samples are shown in Table 4. The highest number of insects collected was found in Ceyhan (472 individuals), followed by Tarsus (200 individuals). Similar to the soybean samplings, *T. castaneum* was recorded in higher numbers than other insect species in all districts. This species was mostly collected from the Ceyhan (342 individuals) and Tarsus (164 individuals). The reasons for the higher concentration of insects in both districts may be related to the higher sunflower production in these districts and thus, the higher number of sunflower seeds coming to the warehouses, and therefore the higher number of samples taken.

The rates of insect species found in the soybean samples according to sampling locations are shown in the Table 5. The most insects were detected in Tarsus (147 adult individuals). This was followed by the Seyhan (60 individuals) and Kadirli. *Tribolum castaneum* was detected in all districts except Sarıçam. This species was mostly recorded in Seyhan (43 individuals) and Tarsus (58 individuals). *Oryzaephilus surinamensis* (53 individuals) and *C. dimitatus* (29 individuals) were found mostly in Tarsus. The numbers of the other species detected were lower compared to the districts and their number varied from 1 to 3 individuals. The higher number of individuals in Tarsus and Seyhan districts may be related to taking more samples from these districts.

In this study, secondary harmful species, mostly *Tribolium* spp. and *O. surinamensis* individuals were collected. Adult individuals of *Sitophylus oryzae*, which are the primary pests of cereals (wheat and corn seeds) and are a common occurrence in high numbers (Işıkber et al. 2005; Mert 2012; Er et al. 2016; Yetkin 2021), were recorded in very low numbers. This issue may indicate that the main habitat of this pest insect species is warehouses , even if it is capable of living in the open areas neighboring the warehouses. In this study, the higher number of *T. castaneum* compared to *T. confusum* in both the sunflower and soybean seed samples may be due to the ecological demands of this species, in other words, the high temperature demand of *T. castaneum* (Rees 2004). There were high densities of this species in the open area around the warehouses, where grains are stored in Adana therefore, hidden places should be investigated carefully for pest insects of stored products, particularly for flour beetles (*Tribolium* spp.). Although *Tribolium* spp. are of secondary importance in stored grains, if the product moisture is high, it can also be fed and reproduce quickly in healthy grains. Işıkber et al. (2016), in the study that they conducted on the stored corns in three different geographical locations:- South Türkiye (Adana, Mersin and Kahramanmaraş Provinces), Southeast (Şanlıurfa Province) and Central Anatolia (Konya Province) inTürkiye , they reported that *T. castaneum* (40%) and *S. oryzae* (40%) had the highest prevalence in the Southern Anatolian Region. Another reason for the widespread and high occurrence of *T. castaneum* in the open field, may be related to the fact that this species develops very high resistance to the phosphine gases in the Southern Provinces of Türkiye (Adana, Hatay, Kahramanmaraş, Mersin and Osmaniye) (Doğanay 2019). Similar to *Tribolium* species, *O. surinamensis* is a species of secondary importance in cereals, and it is a major problem especially in stored oilseeds (eg peanuts) (Rees 2004). *Tribolium castaneum* and *O. surinamensis* prefer stored grains and oilseeds, and they also cause toxigenic fungi infestations on the stored products, such as *Aspergillus* species, which infect insect's body parts and in their feces, and are thus spread in warehouses (Howe 1965; Rao et al. 2010; Tucker et al. 2014).

Table 3. Insect species found in sunflower seed samples, number of adults, and percentages of species in total adults

Species	Number of samples found	Frequency (%) in samples	No of individuals	Percentage of adults
Coleoptera				
Bostrychidae				
Rhyzopertha dominica	1	1	1	0.12
Curculionidae				
Sitophilus oryzae	5	5	7	0.85
Laemophloeidae				
Cryptolestes turcicus	10	10	10	1.20
Nitidulidae				
Carpophilus dimitatus	17	17	30	3.62
Silvanidae				
Oryzaephilus surinamensis	26	26	42	5.01
Tenebrionidae				
Tribolium castaneum	67	67	621	74.91
Tribolium confusum	29	29	50	6.03
Psocoptera				
Lipocelidae				
Liposcelis entomophila	20	20	68	8.20

Table 4. Number of adult individuals of insect species in soybean seeds by districts in 2020

Insect species	Ceyhan	Kadirli	Karataş	Kozan	Sarıçam	Seyhan	Tarsus	Yüreğir	Total
Lasioderma serricorne	0	1	0	0	0	2	3	0	6
Sitophilus oryzae	0	0	2	0	0	0	2	0	4
Cryptolestes turcicus	0	1	0	1	0	0	1	0	3
Carpophilus dimidiatus	2	15	3	12	4	7	29	0	72
Oryzaephilus surinamensis	1	12	17	1	0	17	53	5	106
Tribolium castaneum	5	31	13	8	0	43	58	15	173
Tribolium confusum	0	0	1	0	0	1	1	0	3
Liposcelis entomophila	0	0	0	1	0	0	0	0	1
Total	8	60	36	23	4	70	147	20	368

Table 5. Number of adult individuals of insect species found in sunflower seeds by districts in 2020

Insect Species	Ceyhan	Kadirli	Karaisalı	Kozan	Tarsus	Sarıçam	Total
Rhyzopertha dominica	1	0	0	0	0	0	1
Sitophilus oryzae	1	0	0	1	3	2	7
Cryptolestes turcicus	4	0	0	3	3	0	10
Carpophilus dimidiatus	20	0	0	6	3	1	30
Oryzaephilus surinamensis	35	0	0	1	5	1	42
Tribolium castaneum	342	41	15	30	164	29	621
Tribolium confusum	33	1	0	1	12	3	50
Liposcelis entomophila	36	2	2	3	10	15	68
Total	472	44	17	45	200	51	829

No damage caused by the insects identified was observed in the soybean, sunflower and weed seeds. This may be related to the short-term storage in the open area. However, weed seeds being together with harvested crops may increase crop moisture (Rees 2004). Because during the harvest period, only the moisture situation in the seeds of these cultivated plants is taken into account.

4. Conclusions

In this study, soybean and sunflowers seeds stored outdoor as heaps for a short time (approximately 15 days) in the open areas of the sampled warehouses before being stored were attacked by the various harmful insects living both in the open area, and in the warehouses. With this study, it was concluded that insects, defined as secondary pests in particular *Tribolium* spp. and *O. surinamensis*, which are transported to the warehouse with the products from outside, may cause damage as much as insect attacks inside the warehouses. Weed seeds coexisting with soybean or sunflower seeds may increase crop moisture and thus, cause the proliferation of the pests, and thus, increased damage. In this case, it is suggested that it is important not to leave the harvested crop seeds in the open area, even for a short time, before it is taken into storage, in terms of preventing the attacks of harmful outdoor insects such as the red flour beetles and the sawtoothed grain beetles. Moreover, it is recommended to spray the products for preventive purposes before storing them.

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Profit efficiency of mushroom cultivation in Antalya, Türkiye

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ABSTRACT

Mushroom is an important fresh vegetable for the Turkish consumer market. However, mushroom production can only be carried out in a few places due to its specific climatic and geological requirements. The amount of mushroom produced in Türkiye was 55455 tonnes in 2020, 33518 tonnes of which (60%) was cultivated in Korkuteli town of Antalya/Türkiye. The main purpose of this research was to estimate the level of profit efficiency and determine factors affecting inefficiency of mushroom cultivation in Korkuteli/Antalya. Accordingly, 60 producers were interviewed in Korkuteli in 2020. Respecting effective exchange rate of 28th October 2020 ($ 1= 8.21 TL) the average per unit profit of producers was calculated as $ 24.98 and average profit inefficiency as 44%. The inefficiency score was estimated against socio-economic items relevant to individual farms or farmers with stochastic profit frontier approach. Gender, education and satisfaction levels of the producer and duration of harvest and registry to the Farmer Registration System (CKS) appeared as factors reducing profit inefficiency. However, age of the farmer, garden use of waste compost and mushroom sales through intermediaries were detected as inefficiency rising factors. Due to the findings, supporting female producers, providing applied training and courses, developing approaches to raise the satisfaction level of producers and supporting CKS registry were proposed. In addition, it was concluded that establishment of a waste compost centre and reopening the producer union, that was shut down earlier, might reduce profit inefficiency.

1. Introduction

Mushroom has been consumed by humans since the hunting & gathering era due to its free availability. Mushroom is used as an ingredient for many industries starting with medicine as well as being considered as a nutrient. In addition to free supplies in the nature, mushroom is also cultivated under controlled conditions. Cultured mushroom can be cultivated across the year under valid climatic conditions.

Cultured mushroom is rich in nutrient value due to herbal protein content and has a specific stance in the Turkish nutrition system. Due to FAO data, 12.27 million tonnes of annual mushroom production in 2009 rose by 69.8% to 20.847 million tonnes in 2019 (FAO 2020). The average amount of mushroom cultivated has been around 17 million tonnes annually. Due to average production ranking, China is the foremost market leader with 83% share and more than 14 million tonnes of production. China is followed by Japan and the USA with around 2.5% shares. Türkiye ranks as the sixteenth with 0.2% share and 35570.73 tonnes of production (FAO 2020). Official statistics of Türkiye (TUIK) revealed that 15000 tonnes of mushroom production in Türkiye in 2004 almost tripled by 2020 and reached to 55455 tonnes. Korkuteli town of Antalya has a specific stance in nationwide mushroom cultivation that town's contribution in national supplies is 67% (TUIK 2020). Therefore, the research was restricted to Korkuteli town of Mediterranean province of Antalya. Accordingly, it was intended within this study to measure the profitability of cultured mushroom of *Agaricus Bisporus* variety and determinants of profitability levels at the producer level. The final objective of the case study was to propose policy moves to assure sustainability of mushroom cultivation in Türkiye.

While the history of mushroom research dates back in time, it is new for Türkiye. While recognition and reproduction of mushroom dates to B.C. in the world, the first recorded production in Türkiye took place in 1960 via trials of an MD named Enver and with seeds brought from Germany (Gunay 2004). Accordingly, there are very few studies in Türkiye regarding both cultivation and economics of mushroom. Some relevant global and Turkish studies were summarised below.

Frempong (2000) searched profits of mushroom producers in the Greater Accra district of Ghana with data from 1995-1999. The benefit/cost ratio of cultivation activity was calculated as 1.35. Mushroom cultivation was acknowledged as profitable with $ 6200000 net present value of sales and 48.24% internal efficiency ratio.

Ozcatalbas et al. (2004) conducted a field survey with 150 producers in Korkuteli to develop solutions to specific production problems. By then, almost 60% of producers had less than 5 years of production experience and main income generation activity of 33% of these producers was mushroom production. While low sales price was considered as a problem by producers, intermediaries complained about the VAT rates. Demir and Sonmez (2011) searched existing economic situation and problems of 156 producers in Korkuteli and more than 90% of producers declared that they had a fair income. The most important problem was compost supplies with 61.53% and more than 78% of producers seemed to use waste compost as fertilizer.

Barmon et al. (2012), researched benefit/cost (B/C) ratios of 30 selected producers in Bangladesh in 2011. The calculated average cost of production per producer was $ 574.63 corresponding to $ 888.02 income on average. With 1.55 B/C ratio, the activity appeared to be profitable.

Mayanja (2018), determined mushroom cultivation profitability in Kampala – Uganda with 52 producer responses from 2016. The evaluation was made with benefit/cost ratio, break-even analysis, data envelopment analysis. The profitability determinants were estimated with multiple regression and efficiency determinants were estimated with Tobit analysis. It was understood that per farmer average gross profit was more than $ 4000 and net profit was $ 2385.31. The break-even point per enterprise was 106.41 kg. Efficiency scores were recorded under different conditions. Under variable returns to scale conditions, technical efficiency was 0.942, distributive efficiency was 0.593 and cost efficiency was 0.557. Under constant returns to scale assumptions, the scores were recorded as 0.681, 0.487 and 0.331 respectively. Tobit estimation results revealed that efficiency was mainly affected by sales price and number of carrier bags. The most important problems faced by producers appeared to be the low sales price in a complementary way and lack of proper consultancy services.

Departing from these research experiences, profit efficiency of mushroom cultivators in Korkuteli Antalya was estimated and evaluated in this study.

2. Materials and Methods

2.1. Material

As noted, Korkuteli is a very significant district for mushroom cultivation in Türkiye. Recognition and acceptance of mushroom production as an alternative income generation activity in Kokuteli - Antalya dates to 1990s, when harsh drought conditions were observed. Over time, compost companies were established and more farmers were supported in mushroom production. The population of the study, number of mushroom growers in Korkuteli was 1200 in 2020 due to TUIK data. However, due to 2019 records of the Farmer Registry System of Ministry of Agriculture and Forestry, the number of registered producers was 122 (MoAF 2020). The sample of field survey was determined as 60 respecting 5% of the population with non-probabilistic purposive sampling. This sample also referred to 49% of officially registered farmers. Choice of purposive sampling was also related to the homogeneity of cultivar scale in the town so that the possibility to manipulate the parameters and estimates was low enough. Therefore, 60 of Agaricus bisporus variety mushroom cultivators were visited in October-November of 2020 and primary data was retrieved with a face-to-face survey. Mushroom cultivation takes place four times per year. Researchers were directed to choose between two cultivation periods, October-November and March-April. The temperatures are similar in these two periods and range between 5 and 22 degrees Celsius due to records of the Meteorological Service of Türkiye (MS 2020). Therefore, researchers undertook the survey in the autumn period considering climatic conditions and time availability.

2.2. Methodology

Different ratios and parametric and non-parametric methodologies are being used in the measurement of efficiency. Parametric stochastic frontier analysis was used in this study. This stochastic approach explains probabilistic effects leading to inefficiency within composite variation in the objective function, i.e. production, cost, or profit (Aigner et al. 1977; Battese and Corra 1977; Battese and Coelli 1995). Profit function is preferred where possible, as the decision-making process for input use was included as an external factor in profit maximization approach (Ali and Flinn 1989; Lau and Yotopoulos 1971; Yotopoulos and Lau 1973; Abdulai and Huffman 1998; Ozkan et al. 2009). The Cobb-Douglas profit function utilised was as follows (Battese and Coelli 1995; Ceylan et al. 2018):

$$\pi_i = f(P_{ij}, Z_{ik})\exp(e_i) \qquad [1]$$

π_i: gross profit ([total sales revenue – variable costs of the ith farm] /amount cultivation land –m^2)

P_{ij}: input price (price of input jth of the ith farm/ amount of output produced - kg)

Z_{ik}: level/amount of kth fixed production factor of the ith farm)

e_i: error term

Augmented form of the Cobb-Douglas gross profit function is as following.

$$\ln\pi = \ln\beta_0 + \beta_1\ln Z_{ik} + \beta_2\ln P_{2i} + \beta_3\ln P_{3i} + \beta_4\ln P_{4i} + \beta_5\ln P_{5i} + \beta_6\ln P_{6i} + \beta_7\ln P_{7i} + (u_i + v_i) \qquad [2]$$

In the equation ln represents linear logarithm. The dependent variable π was gross profit per unit land in m^2. Z_{ik} is the amount of fixed factor, P_{2i} is the amount of land utilised for mushroom cultivation (m^2). The remaining independent variables were calculated per unit land used for mushroom farming in m^2. P_{3i} was compost cost, P_{4i} was pesticide/herbicide cost, P_{5i} was energy cost (electricity, water, gas), P_{6i} was temporary labour cost (daily worker payment), P_{7i} was transportation cost (compost and compost disposal carriage) respectively.

In this equation 2, u and v represent the error term. Error term of the profit function is the sum of inefficiency score and random errors. Also, per unit refers to the amount produced (kg) in the ith farm. With estimation of this profit function, effects of variable costs on the profit level can be measured. Yet, the objective of the research was to determine socio-economic factors affecting profit/loss situation of mushroom producers. It is accepted that error term variance of the profit function represents the sum of inefficiency and random variance as demonstrated below (Battese and Cora 1977; Battese and Coelli 1995; Kumbhakar and Lovell CAK 2000).

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \qquad [3]$$

The inefficiency index (KEI) was retrieved via inverse logarithm implementation to the error term for each observation – farm.

$$KEI_i = (1 - \exp[-u_i]) \qquad [4]$$

Afterwards, the inefficiency index was estimated against the factors expected to affect it.

$$\mathrm{KEI_i} = \mathrm{f}(\mathrm{C_i}, \mathrm{Y_i}, \mathrm{E_i}, \mathrm{M_i}, \mathrm{H_i}, \mathrm{A_i}, \mathrm{K_i}, \mathrm{S_i})) \quad [5]$$

C_i: Gender of producer
Y_i: Age of producer
E_i: Education level of producer
M_i: Satisfaction level from mushroom cultivation
H_i: Harvest duration
A_i: Use of compost disposal in the garden
K_i: Official farmer registration status (CKS)
S_i: Sales venue – use of intermediary

The analysis was conducted in STATA 16 following the methodology proposed.

3. Results and Discussion

Mushroom cultivation profitability was evaluated for inefficiency. While net profit represents the success of the managerial process of the enterprise or the farm, gross profit represents the success of productive activities. Accordingly, fixed costs were separated from the statistical measurement and inefficiency interpretation process.

Prior to proceeding, the aggregate and average figures should be noted. The average amount of production for 60 producers in October-November 2020 was 17951 kg. The amount produced by 42 growers was below average. Average per kg price was $ 0.73 and 53 producers (88%) seemed to receive above this average. Average sales revenue was $ 1449.48 and 43 producers (72%) were receiving below this level. The average gross profit was $ 4320.58 and 65% of operators' profit level was below this average. Average profit per kg was recorded as $ 0.16 with respect to the effective exchange rate of 28th October 2020 ($ 1= 8.21 TL). Net profit average on the other hand was $ 2157.49 and 21 producers were in loss due to their declarations.

3.1. Stochastic profit estimation

After a descriptive evaluation of the profit structure, effects of cost items on the profit and impacts of socio-economic factors on profit efficiency were estimated consecutively. Prior to analyses, the linear distribution structures were checked. The profit and cost variables appeared as non-linear on level and logarithmic transformation was made as referred in the literature. The normality of transformed profit and cost accounts was checked with the Shapiro-Wilk W test (Shapiro and Wilk 1965) and unit sales cost (duty and commission payments) and unit cover soil cost were removed from the equation.

The correlations between variables were checked afterwards. Negative correlations were detected between production land and cost items regarding pesticide/herbicide, compost and energy use. In addition, there was a positive correlation between compost cost and pesticide/herbicide and energy use costs. These relationships led to a suspicion of multicollinearity and variance inflation factors (VIF) of variables were calculated and evaluated. If VIF is found out to be equal or more than 10, existence of multicollinearity is suspected (Webster 1995). In contrast to existing relationships between variables, multicollinearity was rejected, and gross profit was estimated in a semi-normal form. The findings were demonstrated in Table 1.

Due to Wald chi-square, detected six independent variables explained 39.25% of variation in the dependent variable or per unit profit. The impact of cultivation land was estimated as -0.57 meaning a reduction of profit by -0.57 units corresponding to a declination of the amount of land by 1 unit. Rising amount of land can be read as rising variable costs. Therefore, the negative impact is an expected economic inference. Rising energy cost per unit led to a reduction in profit by 0.87 units. Therefore, climatic conditions should be kept under control for cultured mushroom cultivation, So, cultivators use air conditioning and electrical energy to provide the most desirable temperatures for heating and cooling. Therefore, rising energy cost reduces profitability as expected.

Table 1. Gross Profit Estimation with Stochastic Frontier (normal/semi-normal model) - (n: 60).

Wald $X^2(6)$ (p> chi2)	39.25 (0.00)	Log likelihood	-79.54	
ln*π* (per unit profit) - Dependent	Coefficient	Std. Error	z	ρ>|z|
$\ln P_{2i}$ (land - m^2)	-0.57	0.15	-3.78	0.00
$\ln P_{3i}$ (compost cost)	0.29	0.42	0.70	0.48
$\ln P_{4i}$ (pesticide/ herbicide cost)	0.50	0.32	1.56	0.11
$\ln P_{5i}$ (energy use cost)	-0.87	0.45	-1.94	0.05
$\ln P_{6i}$ (temporary labour cost)	-0.01	0.21	-0.09	0.93
$\ln P_{7i}$ (transportation cost)	0.32	0.20	1.57	0.11
Constant	8.35	2.21	3.77	0.00
$\ln\sigma_v^2$	-1.47	0.81	-1.81	0.07
$\ln\sigma_u^2$	0.61	0.43	1.41	0.15
σ_v	0.47	0.19		
σ_u	1.35	0.29		
σ^2	2.07	0.66		
λ	2.84	0.46		
LR test (Likelihood ratio) of σ_u=0: $X^2(p)$= 2.68 (0.051)				

It was seen that the statistical likelihood values of compost, pesticide/herbicide, labour and transportation costs were high. Deterministic tests ran prior to analyses only enabled a general assessment of the parameter estimates. Checking out the estimate signs in Table 1, compost, pesticide/herbicide and transportation costs raise profit levels and profitability attached. Yet, the impact of labour cost was reverse.

It is also important to understand these effects more in detail. Compost cost is rather significant in mushroom cultivation, being the most important input of the process. Scale efficiency can be considered for inference of its positive effect. With a larger closed production warehouse in m^2 and rising production, more compost is required, and rising compost expenditure can be interrelated with rising production and sales revenue the sales revenue is expected to rise. It is almost similar for pesticides/herbicides. Even though climatic conditions are taken under control for the health of compost as a production material, compost is open for diseases due to its nature. Use of herbal medicines is allowed in mushroom cultivation under certain limitations. So, with more pesticide/herbicide costs, more sales revenue and profit are expected. The amount of compost and size of the warehouse also contribute to an explanation of the transportation costs. Subsequently, as these cost items rise, the production and attached gross profit rises as well and this can be read as a positive impact. On the contrary, the effect is minimum for labour cost in a negative direction. As daily labour requirement and use may include implicit costs as well, temporary labour use seemed to have a negative effect. In other terms, temporary labour requirements may also be related to the process planning disruptions and may be read as rising direct costs and thus reducing efficiency.

Following stochastic profit frontier estimation, normality of error terms and existence of heteroscedasticity were checked to confirm the valid specification of the model. The normality of residuals was tested with Skewness/Kurtosis tests (Pearson 1905). With 0.31 Skewness and 0.68 Kurtosis values, a normal distribution characteristic was confirmed (Hair et al. 2018).

The existence of odd values in the data set is considered as heteroscedasticity. When error term variance changes due to variations in independent variables, there is a variance problem (Gujarati 1995). This possibility was checked with the Breusch-Pagan / Cook-Weisberg test. With p value above 0.05, heteroscedasticity was rejected (Breusch and Pagan 1976; Cook and Weisberg 1983). With homoscedastic error variance, it was understood that the model was formed correctly even if some parameters appeared to have low significance. Therefore, it was understood that the factors affecting profit inefficiency could be estimated and inferred for these 60 cultivators.

3.2. Inefficiency frontier estimation

The stochastic analysis was followed by retrieving inefficiency scores with inverse logarithm application to error terms' variance $\mathrm{KEI_i} = (1 - \exp[-\mathrm{u_i}]))$. The scores indicated that the inefficiency ranged between 0.04 and 80 % and the average inefficiency for 60 producers was 44%. After determination of the inefficiency set, profit inefficiency was estimated against previously determined economic, social and farmer related characteristics.

The frontier estimation results were demonstrated in Table 2. To replicate, the average inefficiency was 44%. With a female farmer, it was understood that inefficiency declined by 9% at 0.10 significance level. With rising age, inefficiency rose by 9%, rising education level reduced inefficiency by 4%. If the farmer was satisfied or had the tendency towards higher satisfaction regarding the mushroom cultivation process, inefficiency reduced by 21%. With longer harvest period allocated, declination in inefficiency was 14%. The declination percentage was 42% when the cultivator was registered in the farmer registry system (CKS). If the farmer had been using compost disposal in the garden, inefficiency seemed to rise by 31% and use of intermediary led to rising inefficiency by 5%. The estimates were significant and their signs or directions of effect were in conformity with economic and social expectations.

4. Conclusions

With this study, the efficiency level of mushroom cultivation and effective factors attached were analysed for Türkiye with respect to a sample from the important cultured mushroom cultivation district of Korkuteli, Antalya. Turning back the profit inefficiency estimates, the average inefficiency was 44% for 60 producers. In other words, 34 of 60 mushroom farms were operating efficiently with respect to the profit they received. The effective factors can be differentiated in terms of the direction of their impact.

Inefficiency reducing factors

- Farmer is female
- Farmer has more education
- Farmer is satisfied with the process
- Farmer is registered officially.
- Harvest duration is longer

Inefficiency rising factors

- Farmer is older
- Farmer uses compost disposal in the garden.
- Farmer maintains sales via intermediaries.

Table 2. Determinants of cultivar inefficiency (σ_u^2) - (n: 60)

Wald $X^2(6)$ (p> chi2)	30.47 (0.00)	Log likelihood	-74.44	
ln (inefficiency score) - Dependent	Coefficient	Std. Error	z	ρ>|z|
C_i (gender)	-0.09	0.67	-0.15	0.08
Y_i (age)	0.09	0.04	1.90	0.05
E_i (level of education)	-0.04	0.29	-0.15	0.08
M_i (satisfaction level)	-0.21	0.24	-0.87	0.03
H_i (harvest duration)	-0.14	0.10	-1.32	0.01
A_i (use of compost disposal in the garden)	0.31	0.71	0.44	0.06
K_i (official registration)	-0.42	0.65	-0.66	0.05
S_i (use of intermediary)	0.05	0.96	0.05	0.09
Constant	6.81	6.96	0.98	0.33
σ_v	0.55	0.14		

Due to the statistical findings, it is possible to propose the following measures to reduce inefficiency or increase efficiency with respect to profit earned.

- Female farmers/entrepreneurs should be supported in mushroom cultivation.
- More on-site and off-site training programmes should be developed for technical aspects of mushroom cultivation and these programmes should be delivered to farmers.
- The farmers should be encouraged to form joint organisations to increase the possibility of accessing more technical and economic support.
- The public sector should propose more agricultural support for establishment of mushroom cultivation facilities.
- Increasing producer registration is important and should be a focus point.
- Increasing traceability of the process is essential for product and process quality. Public organisations should promote traceability for further gains.
- Younger farmers should be supported to enter the market or take over management of existing structures.
- Support should be provided to mushroom processing in the form of pickles or canned form to increase value-added activities. Producers should be directed towards industrialisation.
- Establishing a specific monitoring mechanism to prevent the use of compost disposal in the gardens is essential. Public sector should act accordingly and provide extension services to farmers.
- Merging compost and mushroom production actors may provide price competition power. Support should be provided to merge, to extend overseas activities or to promote international trade.

Findings and inferences of the field study have portrayed the sustainability of problems in mushroom cultivation in Türkiye. There were non-governmental initiatives formed to organise the sector and represent actors. Yet, the attempts have been previously unsuccessful. Producer and merchant actors in the sector and policy maker/implementer organisations recognize the need to organise the sector for more efficiency in economic and social manners.

Considering the target district and its economic dependency on mushroom production, problems in the sector cannot be neglected and more focused economic planning is essential. The enterprises should recognise their need for profits and importance of mushroom in the Mediterranean diet so that further investments can be made. Especially, in countries where mushroom is recognised as a traditional producer/consumer product, actions to enrich production schemes, develop international trade lines and contacts should be considered seriously. Such policies and measures might assure sustainability of the sector. Therefore, it can be said that this study suggests the recognition and development of mushroom economics as a research and policy field. Besides, socio-economic proposals can be considered as valid in most of the mushroom-producing countries for commercialisation of production activities.

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Determinants of dried fruit products sector export: A gravity model for Türkiye

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ABSTRACT

Agriculture contributes to economic development as well as meeting the basic nutritional needs of a society. The dried fruits and dried fruit products industry is one of the leading industries contributing to the national economy and forms a significant part of the agricultural industry. This study investigates the determinants of Türkiye's exports of dried fruits and dried fruit products using the gravity model. In this context, the data for the 2005-2021 period for 78 countries importing dried fruits and dried fruit products from Türkiye were analyzed using the Poisson Pseudo Maximum Likelihood estimator (PPML). The analysis revealed that the GDP of Türkiye and the importing country, nominal exchange rate, EU membership of the importing country, the availability of a free trade agreement with the importing country and the average surface temperature changes, positively impact Türkiye's exports of dried fruits and dried fruit products. Whereas the distance between countries, which is a good indicator for transportation costs, negatively affects Türkiye's exports of dried fruits and dried fruit products. The results of the analyses show that exports of dried fruits and products exhibit similar results to that of exports of agricultural products. Additionally, the gravity model for exports of dried fruits and dried fruit products is valid for Türkiye.

1. Introduction

The agricultural industry is dependent on a variety of natural factors such as weather conditions, climate change, soil quality, water resources and other environmental factors. Therefore, the agricultural industry carries a greater element of uncertainty and risk compared to other industries. However, agriculture is an indispensable industry across the globe due to its provision of raw materials and capital to other industries, feeding the growing population, contributing to national revenue and employment, etc., as well as its impact on ecological balance. Agriculture has played an integral role in the economic and social development of countries throughout history and is expected to continue to play a major role in the future (Erdinç and Erdinç 2018).

The globalization of international trade has greatly contributed to the development of agribusiness in recent years (Qiang et al. 2013). With the growth of agricultural exports, it has increased the productivity of domestic production in the national economy, improved the welfare of those employed in the agricultural industry, and provided resources for other imports (FAO 1995). In addition to providing foreign exchange, agriculture also contributes to the growth of related industries such as production, packaging and logistics. As agriculture contributes to the economic development of countries, its weight in the overall economic structure gradually decreases over time. However, even in this case, agriculture deeply concerns all segments of the society with its economic, social and environmental aspects (Doğan et al. 2015).

Türkiye, which is one of the important actors in the global agricultural economy with its rich biological diversity, different climatic and geographical characteristics and developed agricultural industry, has 0.8% of the world's total farmland and accounts for 1.35% of the world's agricultural production. Ranked among the top 10 countries in the world's agricultural production, with an annual agricultural production value of USD 50 billion, Türkiye is also one of the countries that have a major say in the world's agricultural products. As a matter of fact, Türkiye, which realizes 1.64% of the world's agricultural exports and 1.14% of its imports, is a country with a foreign trade surplus. Türkiye's fertile soils and large agricultural lands allow fruits and vegetables to be grown in high quality and good conditions thanks to its climatic diversity in different regions (AKİB 2023). Türkiye is a leading country in the trade of dried fruits and dried fruit products with its wide product range and high product quality.

Agriculture is a fundamental component of the Turkish economic system, as in other developing countries, and plays a critical role in the development of the country. Although its relative importance is gradually decreasing in the process of economic development, the agriculture sector continues to be one of the main pillars of socioeconomic life in Türkiye today as it was in the past. Table 1 shows Türkiye's export data for the 2005-2022 period. As shown in Table 1, total exports of Türkiye increased by 246% from 2005 to 2022. The growth of the agricultural industry has been in parallel with the growth in total exports. In 2005, agricultural exports amounted to over USD 9.5 billion, reaching USD 34 billion in 2022. During this period, dried fruit exports increased by 147% from USD 636 million to

USD 1.6 billion. As shown in Table 2, Türkiye ranks high in the global exports of dried fruits and dried fruit products. Türkiye ranks first in the world in the export of raisins, dried apricots and fresh or dried figs, and second in unshelled pistachios. Raisins, dried apricots and dried figs are the most exported products. It is noteworthy that exports of dried apples and dried plums are very small compared to other products. Türkiye's share in the global export of dried apricots and fresh or dried figs is high. The three products with the highest unit prices in USD are pistachios, walnuts and almonds. Table 2 shows that Türkiye exports almonds mostly to nearby countries and dried apricots to distant countries.

Due to Türkiye's position in this industry, it is important to investigate the factors affecting the export of dried fruits and dried fruit products. Given the country's position in global trade, the contribution of dried fruit and vegetable exports to the national economy can be increased by continuing to pursue a policy of growth in exports. This study differs from the literature in several points. First, exports of agricultural products or exports of fruits and vegetables have been studied in the literature, but the number of studies investigating exports of dried fruits and dried fruit products in Türkiye is not sufficient. There are also studies investigating the export of dried figs, raisins and dried apricots, but there is no study analyzing the entire industry using panel data. Another difference is the variables used in the present study. The use of agricultural loans provided by FAOSTAT and changes in average surface temperature tracked by NASA in the panel gravity model is yet another difference.

This study analyzes the determinants of Türkiye's exports of dried fruits and dried fruit products using the gravity model. The second section of the study includes a literature review on exports of dried fruits and dried fruit products and agricultural exports, both with time series and panel data. The third section introduces the data used in the study and provides information about the panel gravity model. The fourth section presents the methodology used in the study and the results of the analysis. The final section of the study, namely the conclusion, provides a general assessment and recommendations.

2. Material and Methods

The gravity model is an economic model that is frequently used to explain trade between countries. This model is similar to Isaac Newton's "Law of Universal Gravitation" in physics. When this law is applied to international trade, countries seem to trade in proportion to their size and the distance between them (Yotov et al. 2016). The first adaptation of the gravity model to international trade was introduced by Jan Tinbergen in 1962. Model 1 shows the traditional gravity model (Tinbergen 1962):

$$F_{ij} = aY_i^{\beta_1}Y_j^{\beta_2}D_{ij}^{\beta_3} \qquad (1)$$

F_{ij}: exports of country i to country j
Y_i: economic size of country i
Y_j: economic size of country j
D_{ij}: geographical distance between country i and country j
a: represents the constant coefficient of the model and $\beta_1, \beta_2, \beta_3$ represent the coefficients of the variables in the model.

According to Model 1, where Tinbergen explains trade flows, although there are many variables that explain foreign trade between countries, the three most important factors are the economic size of the exporting and partner countries and the geographical distance between the countries. These three factors indicate that exports are positively affected by the economic size of the exporting and partner countries, while distance is negatively affected by transportation costs. Variables other than these three factors seem to have a limited effect on exports (Tinbergen 1962). Model 2 is a linearly rearranged representation of Model 1 by taking its logarithm (Tinbergen 1962):

$$LogF_{ij} = \vartheta + \vartheta_1 logY_i + \vartheta_2 logY_j - \vartheta_3 logD_{ij} + \varepsilon_{ij} \qquad (2)$$

In Model 2, $\vartheta_1, \vartheta_2, \vartheta_3$ are the coefficients of the independent variables to be estimated and ε_{ij} is the error term in the model. Economic size and geographical distance are the main variables of the gravity model, but Model 2 can be extended with appropriate variables in econometric studies. In the extended gravity model, a number of different factors such as the population of the countries, social ties, trade agreements and spatial conditions can be added to the model (Dayıoğlu and Kaplan 2016).

After the 1970s, there have been several studies trying to establish the theoretical foundations of the gravity model. In one such study, Anderson (1979) reduced the constant elasticity of substitution of the expenditure system from the Cobb-Douglas

Table 1. Export Values ($) and rates of change (%) by industry in Türkiye

Sectors	2005	2022	Rate of Increase (%)
A. Total exports	73426151	254209535	246.2%
I. Manufacturing	62243740	185880772	198.6%
II. Mining	1513969	6469002	327.3%
III. Agriculture	9668441	34246492	254.2%
I. Dried fruit exports	636747	1573464	147.1%

Source: TİM (2023) Türkiye Exporters Assembly. https://tim.org.tr/tr/ihracat-rakamlari Accessed 26 February 2023.

Table 2. Data of Türkiye's dried fruits and dried fruit products industry (2021)

Products	Exports	Price (USD)	Share in global exports	Global ranking	Average distance
Raisin	478849	1862	27.6%	1	3582
Dried apricot	338351	3856	72.3%	1	5042
Fresh or dried fig	330514	3623	42.8%	1	3965
Pistachio (unshelled)	174713	12893	22.9%	2	2314
Almond (unshelled)	110879	6757	2.0%	7	1515
Walnut (unshelled)	45379	6938	1.8%	8	2321
Dried apple	10408	1751	7.4%	4	2392
Dried plum	331	3194	0.5%	15	3901

Source: TradeMap (2023) Statistical database.

production function and in this model, consumers are able to distinguish that goods differ depending on their country of origin (Demir and Bilik 2018). The main disadvantage of Anderson's (1979) model is that it does not consider price differences. In this respect, Bergstrand (1985), who later emphasized price differences in the model, proposed a supply-side gravity model that includes price differences. Bergstrand (1985) included the income levels of exporting and importing countries and the distance parameter representing the transportation cost for importers (Zaimovic 2022). Based on the general gravity model, models that include extended cases of Model 2 are given below:

$$LogEXP_{ijt} = \beta_0 + \beta_1 logTRGDP_{it} + \beta_2 logPGDP_{jt} - \beta_3 logDistance_{ij} + \beta_4 ER_{ij} + \varepsilon_{ijt} \quad (3)$$

$$LogEXP_{ijt} = \alpha_0 + \alpha_1 logTRGDP_{it} + \alpha_2 logPGDP_{jt} - \alpha_3 logDistance_{ij} + \alpha_4 logLOAN_{ij} + \varepsilon_{ijt} \quad (4)$$

$$LogEXP_{ijt} = \gamma_0 + \gamma_1 logTRGDP_{it} + \gamma_2 logPGDP_{jt} - \gamma_3 logDistance_{ij} + \gamma_4 logTMP_{ij} + \varepsilon_{ijt} \quad (5)$$

$$LogEXP_{ijt} = \delta_0 + \delta_1 logTRGDP_{it} + \delta_2 logPGDP_{jt} - \delta_3 logDistance_{ij} + \delta_4 EU_{ij} + \varepsilon_{ijt} \quad (6)$$

$$LogEXP_{ijt} = \theta_0 + \theta_1 logTRGDP_{it} + \theta_2 logPGDP_{jt} - \theta_3 logDistance_{ij} + \theta_4 FTA_{ij} + \varepsilon_{ijt} \quad (7)$$

In these models, i represents Türkiye, j represents partner countries (1,2,3,…,78), t represents time (2005-2021) and ε_{ijt} represents the error term. Table 3 shows definitions and sources of the variables used in the study. EXP is Türkiye's exports of dried fruits and dried fruit products, PGDP is the GDP of the partner country, TRGDP is the GDP of Türkiye and distance is the distance between the capitals of the countries in kilometers. In addition, ER is the nominal exchange rate, LOAN is the loans provided to the agricultural industry in foreign currency, TMP is the change in the average annual surface temperature, EU is the EU membership of the partner country, and FTA is a dummy variable indicating the existence of a free trade agreement with the partner country.

3. Results and Discussion

In econometric studies, the panel gravity model is estimated with the Least Squares (LS) method by taking the logarithm of the series. Due to the use of the LS method, the error term is assumed to have constant variance (Kaplan 2016). However, Westerlund and Wilhelmsson (2011) showed in their study that this assumption is not always true and highlighted that the traditional fixed effects estimator is biased in this case. Therefore, Westerlund and Wilhelmsson (2011) argue that it would be correct to use the fixed effects Poisson Pseudo Maximum Likelihood estimator with bootstrap standard errors to analyze the gravity model (Keskin 2019).

In their study, Santos Silva and Tenreyro (2006) identified through Monte Carlo simulation experiments that the constant variance is neglected by estimating logarithmized series (Santos Silva and Tenreyro 2006). In addition, if there are zero observations in the dependent variables, there is a problem in the estimation of the gravity model since the logarithm cannot be taken. Removing zero observations from the series or assigning very small values does not solve this problem (Keskin 2019). The use of the PPML estimator in cases of changing variance and zero observations in dependent variables in gravity model analysis yields more robust and consistent results than other estimation methods (Solmaz and Bayraktutan 2020). Therefore, this study utilizes the PPML estimator. Table 4 shows the results of PPML estimation.

Table 3. Definitions and sources of the variables used in the study

Variables	Definitions of Variables	Source
EXP	Türkiye's exports of dried fruits and dried fruit products	Türkiye Exporters' Assembly
TRGDP	GDP of Türkiye	World Bank
PGDP	GDP of the partner country	World Bank
Distance	Distance between the capital of Türkiye and the capital of the partner country in km	https://tr.distance.to/
ER	Nominal Exchange Rate (Buying)	The Central Bank of the Republic of Türkiye
LOAN	Türkiye's foreign currency denominated loans provided to the agricultural industry	FAOSTAT
TMP	Changes in annual average surface temperature	NASA
EU	Dummy variable indicating the EU membership of Türkiye's trade partner	Ministry of Foreign Affairs
FTA	Dummy variable indicating the existence of a free trade agreement between Türkiye and the partner country	Ministry of Trade

Table 4. PPML Estimation results

Variables	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	-0.533278	-0.33058	0.0468325	0.341628	-0.5532508	-0.493948
TRGDP	0.0829188*	0.075297*	0.063752*	0.048635*	0.083422 *	0.076878*
PGDP	0.0522198*	0.051949*	0.0519728*	0.051996*	0.0502569*	0.080995*
Distance	-0.0474839*	-0.04728*	-0.047302*	-0.04732*	-0.041556*	-0.046957 *
Exchange rate		0.003689*				
Agricultural loan			-0.008402*			
Temperature				0.087101*		
EU membership					0.0283924*	
FTA						0.0107523**

*represents 1% level of significance, while ** represents 5% level of significance.

According to the PPML estimation results in Table 4, it is concluded that the gravity model is valid for Türkiye's exports of dried fruits and processed products. It has been determined that the GDP of Türkiye and partner countries positively affects exports, while the distance has a negative effect. In his seminal work, Tinbergen (1962) states that expected signs for economic variables in explaining international trade are positive, indicating a positive relationship, while distance has a negative sign. The empirical literature on agricultural products also confirms these findings. (Erdem and Nazlioglu 2008; Atif et al. 2017; Kaplan 2016; Işın 2017; Sapa ve Droždz 2019; Arı ve Sayar 2020). However, the studies conducted have also reached findings indicating that distance does not have an impact on agricultural product exports (Atici and Guloglu 2006; Potelwa et al. 2016), or that an increase in per capita income of the partner country reduces exports (Abdullahi et al. 2022). The influence of exchange rates on agricultural product trade in a country is an important indicator for understanding the problems in economic development and trade in agricultural products (Schuh 1974). Indeed, it has been determined that the addition of the exchange rate variable to the model reveals that an increase in the exchange rate positively affects exports. The same result has been reached in studies conducted by Gündüz (2010), Nazlioglu and Erdem (2011), Verter and Bečvářová (2014), Atif et al. (2017), Orman and Dellal (2021), and Awoderu et al. (2022). Unlike these studies, Fidan (2006) has expressed that the real exchange rate does not have a significant impact on agricultural exports. Abdullahi et al. (2022), on the other hand, stated that currency depreciation negatively affected agricultural exports. In the study, it was found that the decrease in agricultural loans taken in foreign currency had a negative effect on exports. Bakari et al. (2020) and Ogunjobi et al. (2022) emphasized that agricultural loans have a positive effect on exports.

Climate change gives rise to unsuitable conditions for the cultivation of agricultural products, affecting the supply side of agriculture through its impact on productivity, arable land, and drought (Huang et al. 2011). Studies in the literature have shown that agricultural products are the most widely affected by climate change, as revealed by Nordhaus (1991), Pearce et al. (1996), and Cline (2007). However, in this study, it has been concluded that incorporating annual average increases in surface temperature into the model leads to an increase in the demand for dried fruit exports. Furthermore, a free trade agreement with importing countries or the importing country being a member of the EU has had a positive impact on dried fruit exports by reducing or completely eliminating trade barriers, thus facilitating trade in dried fruits. In their study analyzing Pakistan's agricultural exports, Atif et al. (2017) arrived at a similar conclusion.

4. Conclusion

With the rapid increase in the world's population, the need for food has increased dramatically, and is still on the rise. In today's world, where clean water resources are gradually diminishing, agricultural lands are shrinking and global warming poses a significant threat, access to sufficient and safe food, which is one of the most fundamental human rights and needs, is among the most important priorities of all nations of the world. In this context, the importance of the agricultural sector, which produces the food needed for societies to exist, is increasing. From this point of view, the agricultural industry is indispensable for all countries regardless of their level of development. Türkiye has a significant agricultural production potential due to its ecological structure and climate characteristics. Its high agricultural potential makes Türkiye a strategic country in agriculture in general and in the production and trade of dried fruits and dried fruit products in particular.

The purpose of this study is to identify the determinants of Türkiye's exports of dried fruits and dried fruit products. To this end, annual data for 78 countries covering the years 2005-2021 were used in the study. As a result of the literature review, the panel gravity model was preferred and analyzed using the PPML estimator. Türkiye's GDP and the importing country's GDP affect exports of dried fruits and dried fruit products positively, while the distance variable affects exports negatively. In addition, devaluation of the national currency, increases in the average surface temperature, the EU membership of the importing country and the existence of a free trade agreement with the importing country increase Türkiye's exports of dried fruits and dried fruit products.

An evaluation of the results of this study as a whole shows that since the depreciation of the national currency increases the exports of dried fruits and dried fruit products, consideration should be given to adjusting the exchange rate policy to the benefit of all components of the industry. In other words, it makes it important to adopt a competitive price policy in order to be persistent in the existing markets and to maintain its effectiveness. Moreover, as the national currency depreciates against foreign currencies, the amount of agricultural loans taken also decreases. Failure to meet the financing requirements needed in the production and trade of products leads to a decrease in both production and exports. In order to eliminate or mitigate this negative effect, decision makers should establish exchange rate policies by taking into account both the competitive price and the loans provided to the industry. A country's production capacity and the advantages of its geographical location, as well as its willingness and efforts to maintain mutual relations with other countries, are effective in its success in foreign trade. Türkiye should develop policies to make free trade agreements with its trade partners. Türkiye should make the best use of its potential and increase its share in the global agricultural products market by ensuring food security for its population as well as ensuring a competitive advantage in foreign markets through the commercial partnerships it develops. This will contribute more to the development of the country.

Considering the importance of the EU in Türkiye's dried fruit exports, it is necessary to closely follow the EU's policies on health, hygiene, quality standards, border regulations, and imports of agricultural products. In addition to the EU, neighboring countries also have a positive impact on Türkiye's dried fruit exports. In this respect, Türkiye's orientation towards bilateral trade relations with the EU and neighboring countries is the right policy, and this is confirmed by the results of the econometric analysis. In addition, exports of dried fruits to distant countries are adversely affected due to transportation costs. Considering the impact of both sharing a border and distance on exports, it is recommended that Türkiye further develop its trade relations with countries in its immediate neighborhood. It is also important for Türkiye to sign free trade agreements with more countries. The depreciation of the national currency has paved the way for Türkiye to be more competitive in international markets and export more, but the depreciation of the national currency has also negatively affected exports as it has increased the cost of foreign currency-denominated agricultural loans. In this respect, a more balanced policy on exchange rates is needed.

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Manufacture and evaluation of a semi-automatic incubator for hatching quail eggs

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ABSTRACT

This research evaluates a semi-automatic incubator designed for hatching quail eggs using locally available materials, with the aim of increasing the quail population, since quails do not naturally incubate their eggs. The objective is to produce meat that competes with broilers as a rich source of protein. The study includes three experimental variables: three incubation temperatures (37, 37.5, and 37.7°C), three turning times (2, 6, and 12 times per day), and three post-hatching periods for chicks to remain in the incubator (2, 6, and 12 hours). The measurements include the percentage of total hatchability within the first 3 hours, as well as rates of deformation and mortality. The results of this research indicated that the manufactured semi-automatic incubator was able to maintain a high hatching percentage, low deformation percentage, and a low mortality percentage when using an incubation temperature of 37.5°C, turning the eggs 12 times per day, and allowing the chicks to stay in the incubator for 12 hours after hatching. Therefore, it is recommended to utilize the manufactured semi-automatic incubator for hatching quail eggs under the above-mentioned parameters.

1. Introduction

Artificial hatching is practiced in many countries to increase the population of domestic quails (*Coturnix japonica*) since they do not naturally incubate their eggs. Despite protein deficiency in poor societies, poultry, and in particular quail, has received less attention than other livestock (Aggrey et al. 2003). As the demand for animal protein rises, quail breeding is seen as an alternative method for meat production, competing with broilers as a protein source. Quail meat and eggs are rich in vitamin E, protein, minerals, fat, and hormones, making them a healthy dietary option that can help people in developing countries who lack some or all of the necessary nutrients for optimal health (Bayomy et al. 2017). Furthermore, quail meat surpasses chicken in terms of protein content. Quails exhibit greater disease resistance, reach sexual maturity at 6 weeks of age, and start laying eggs at 50 days of age (Randall and Bolla 2008). Additionally, quails have the advantage of reaching sexual maturity at a younger age. On average, quails produce approximately 280-300 eggs per year, weighing 19 g each (Kaur et al. 2008). Moreover, quail farming has higher production and a lower cost-to-benefit ratio compared to chicken farming.

The process of incubating embryonic eggs until the parents hatch them is known as the "incubation egg process" (Aru 2017). Artificial hatcheries are crucial for hatching eggs and are widely used in intensive poultry production to meet the increasing demand for poultry products. Temperature stability is a key factor in the incubation process, as it is maintained by the parent while sitting on the eggs. This helps maintain a constant temperature required for the fetus's growth during the specified incubation period. Eggs are generally placed in the incubation phase to facilitate successful hatching, and sufficient moisture availability is essential during the incubation process.

The eggs incubator is a device, similar to a box, that can regulate temperature, humidity, and other factors to promote various stages of fetal growth in the egg, until the hatching process (Umar 2016). There are two main types of incubators available on the market: forced air and still air. The first type circulates air using an exhaust fan, while the second type uses convection air exchange, where cold air enters and heated air exits through ventilation holes. Without an exhaust fan, a still air incubator cannot circulate the air. An exhaust fan is essential to maintain the incubator's heat, moisture level, and oxygen content (Nakage et al. 2003). Researchers have been working on developing incubators for different types of eggs, including chicken (Schmitt 2015), quail (Deka et al. 2016), partridge (Nakage et al. 2003), and others. These researchers have developed incubators with automated control systems, including temperature (Ohpagu and Nwosu 2016), humidity (Schmitt 2015), egg rotation (Ramli et al. 2015), and others, based on microcontroller technology (Ali and Amran 2016; Abdul-Rahaim et al. 2015).

Before placing an egg inside the incubator, it is crucial to assess its quality, as the likelihood of successful hatching significantly decreases if the egg is of low quality. For Japanese quails, the incubation period lasts between 17 and 19 days (Aru 2017), with a temperature range of 36.5°C to 37.5°C19±0.5°C (Schmitt 2015), and a relative humidity range of 50% to 65% (Umar et al. 2016). To prevent the embryo from sticking to the eggshell during incubation, the egg must be turned by 45° every four hours (Mashhadi et al. 2012).

Only a few studies on quail incubation have been published since domestic quail do not naturally incubate their eggs. Therefore, by artificially hatching them, we can produce chicks.

The objective of this research was to construct and evaluate a low-cost incubator using simple electronic components and local materials. The incubator allows control of temperature and humidity, and a manually operated mechanism was used to turn the quail eggs throughout the 17 days required for the day-old chicks to hatch.

2. Materials and Methods

The current study was conducted at a private farm located at EL-Sharqia Government, Egypt. The research consisted of two stages. The first stage involved gathering fertile eggs, while the second stage involved manufacturing and evaluating a semi-automatic incubator for quail eggs.

2.1. Incubator description and structure

A rectangular box, shown in Figure 1, has been constructed for manufacturing the incubator. The incubator is designed for small-scale producers and has a hatching capacity of 350 eggs per cycle. It was constructed at a private workshop. As depicted in Figure 1 and 2, the incubator includes a hatching chamber, egg trays, a hatch box, an electric heater, a fan, a water pan, a hygrometer, and a digital thermostat.

2.1.1. Hatching chamber

The hatching chamber has a wooden body with an aluminum-bar jacket made of thermally insulated material. The metallic wall has a thickness of 5 cm. The dimensions of the chamber are 70 cm length, 50 cm width and 50 cm height.

2.1.2. Egg trays and hatching box

Inside the hatching chamber, two egg trays (56 cm long and 35 cm wide) and a hatching box were constructed. Each tray can accommodate 175 eggs for 15 days, after which they are transferred to the hatching box for an additional 3 days in the same incubator.

2.1.3. Electric heater

An electric heater with a 2000 watt output provides heat inside the hatching chamber. The electric heater is controlled using a digital thermostat.

2.1.4. Digital Thermostat

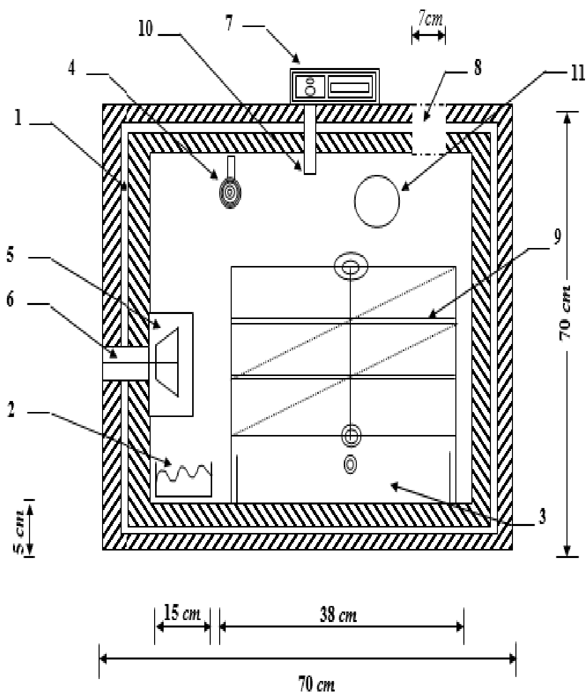
The temperature inside the hatching chamber is adjusted by a thermostat with an accuracy of 0.1°C. It operates within the appropriate temperature range of 5-50°C.

2.1.5. Water Pan

A water pan with dimensions of 10×15×50 cm is placed under the fan inside the hatching chamber to control the relative humidity within the desired range of 0-100%.

2.1.6. Hygrometer

A hygrometer is placed inside the hatching chamber to continuously monitor humidity levels. The eggs are automatically turned at a 45° angle with the help of a timer. Two openings in the hatching chamber are used for natural ventilation.



1- Double insulation wall.
2- Water pan.
3- Hatcher box.
4- Light.
5- Fan + Electric heater.
6- Vent.
7- Digital thermostat.
8- Vent.
9- Eggs tray.
10- Temperature sensor.
11- Hygrometer.

Figure 1. The schematic diagram of the semi-automatic incubator.

Figure 2. The semi-automatic incubator

2.2. Experimental procedure

Uniformly sized quail eggs, from a single production day, were collected for the incubation process and placed inside the hatching trays.. Cracked or extremely unclean eggs were excluded from the investigation. All eggs were thoroughly cleansed with a lukewarm water solution of the mild disinfectant Savlon before setting. The incubator box (hatching tray) was extensively fumigated with formaldehyde and potassium permanganate before laying the quail eggs. Pankaj et al. (2016) also recommended turning the quail eggs until the 15th day of incubation. Candling of the eggs was performed every alternate day using a torchlight, and one fertilized egg was sacrificed to monitor the embryo's developmental pattern. A pan of water was placed in the incubator box to maintain the ideal humidity for hatching. The humidity was adjusted to 50% during the period from 1 to 15 days and 75% for days 15 to 18. On day 7, all eggs were removed from the incubators, and their fertility was assessed using candles. On day 19 of incubation, quail chicks were counted and removed from the hatcher.

2.2.1 Evaluated Variables

Three variables were studied:

1. Incubation temperatures (T), °C: Three incubation temperatures of 37, 37.5, and 37.7°C .

2. Turning times per day (R), times/day: The eggs were manually turned every 12 hours, 4 hours and 2 hours, resulting in three turning times per day of 2, 6, and 12 times.

3. Periods for chicks to stay in the incubator after hatching (P), h: Three periods for chicks to stay in the incubator after hatching of 2, 6, and 12 hours were investigated.

2.2.2. Measurements

The number of unhatched eggs, newly hatched quail chicks, and the number of hatched chicks within the first 3 hours of day 19 were counted. The chicks were also checked fordeformities , and the findings were recorded. The following formulas were used to determine the hatching parameters:

$$Hatchability\ percentage\ (\%) = \frac{Number\ of\ hatched\ chicks}{Total\ number\ of\ eggs\ set} \times 100 \quad (1)$$

$$Hatchability\ percentage\ at\ the\ first\ 3\ h\ (\%) = \frac{Number\ of\ hatched\ chicks\ at\ the\ first\ 3\ h}{Total\ number\ of\ chatched\ chicks} \times 100 \quad (2)$$

$$Deformation\ percentage\ (\%) = \frac{Number\ of\ chick\ deformities}{Total\ number\ of\ hatched\ chicks} \times 100 \quad (3)$$

$$\text{Mortality percentage related to incubation temperatures and turning times per day}\ (\%) = \frac{Number\ of\ dead\ embryos}{\text{Total number of eggs set}} \times 100 \quad (4)$$

$$\text{Mortality percentage related to periods for chicks to stay in the incubator after hatching}\ (\%) = \frac{Number\ of\ dead\ chicks\ during\ incubation}{\text{Total number of}\ hatched\ chicks} \times 100 \quad (5)$$

2.2.3. Statistical analyses

Data on hatchability (%), deformation (%) and mortality (%) were edited in MS Excel (Microsoft Corporation, Redmond, WA, USA). The factorial design of the experiment was used to evaluate the performance of the developed machine. The data were statistically analyzed using the method of Stokes et al. (2012) to determine the significant effect of the mentioned variables on the study based on a probability of $P<0.05$. The experiments were conducted three times, and all graphs were drawn using Microsoft Excel 2016.

3. Results and Discussion

3.1. Effect of incubation temperatures (°C) and turning times per day on hatchability (%)

Regarding the effect of incubation temperatures and turning times per day on hatchability percentage, Figure 3 demonstrates a clear relationship. Increasing the incubation temperature up to 37.5°C positively impacted the hatchability percentage, especially when combined with increased turning time per day. The highest hatchability percentage of 95.06±1.32% was achieved with an incubation temperature of 37.5°C and 12 turning times per day. On the other hand, the lowest hatchability percentage of 26.98±1.27% was observed at an incubation temperature of 37°C and 2 turning times per day. The improved hatchability can be attributed to the increased frequency of turning, which prevents the embryo from sticking to the shell during incubation. This finding aligns with the study by Yoshizaki and Saito (2012) who reported a hatchability percentage of 24% under similar conditions.

3.2. Effect of incubation temperatures (°C) and turning times per day on hatchability (%) in the first 3 hours

A direct relationship was observed when examining the effect of incubation temperatures and turning times per day on hatchability in the first 3 hours (Figure 4). The highest mean hatchability percentage in the first 3 hours was 92.22±3.04% achieved with an incubation temperature of 37.5°C and 12 turning times per day. Conversely, the lowest mean hatchability percentage at the first 3 hours was 24.03±3.31% under an incubation temperature of 37°C and 2 turning times per day.

3.3. Effect of incubation temperatures (°C) and turning times per day on deformation (%)

In terms of deformation, Figure 5 illustrates the impact of incubation temperatures and turning times per day. Increasing the incubation temperature up to 37.5°C resulted in a decrease in the percentage of deformities when combined with a higher frequency of turning. The minimum percentage of deformities observed was 3.75±0.52% at an incubation temperature of 37.5°C and 12 turning times per day. Conversely, the maximum percentage of deformities 87.19±1.53% was recorded at an incubation temperature of 37°C and 2 turning times per day.

3.4. Effect of incubation temperatures (°C) and turning times per day on mortality (%)

The relationship between incubation temperatures, turning times per day, and mortality percentage is presented in Figure 6. Direct relationships are evident, with the minimum mortality percentage of 4.94±1.32% observed at an incubation temperature of 37.5°C and 12 turning times per day. In contrast, the maximum mortality percentage of 73.02%±1.27 was recorded at an incubation temperature of 37°C and 2 turning times per day.

3.5. Effect of incubation temperatures (°C) and staying period (h) on mortality (%)

Furthermore, the study examined the effect of incubation temperatures and staying period on mortality percentage (Figure 7). The results demonstrate a direct relationship, with the minimum mortality percentage of 9.32±0.06% observed at an incubation temperature of 37.5°C and a staying period of 12 hours. Conversely, the maximum mortality percentage of 34.64±7.48% was recorded at an incubation temperature of 37°C and a staying period of 2 hours. It is worth noting that quail chicks are particularly sensitive to temperature, and a longer stay in the incubator after hatching contributes to reduced mortality rates.

In summary, the results indicate that the hatchability percentage decreases, the deformation percentage increases, and the mortality percentage increases when the incubation temperature deviates from the optimal 37.5°C. These findings are consistent with Rashid (2014), who reported significantly higher hatchability at an incubation temperature of 37.5°C. Additionally, maintaining a minimum of 12 turning times per day is crucial for preventing deformities and ensuring successful hatching, as explained by Ramli et al. (2017). The deformation percentage is also influenced by the temperature, with higher temperatures leading to increased deformities. The combination of optimal temperature and an adequate number of turning times significantly impacts the hatchability percentage.

Overall, these results provide valuable insights into the optimal incubation conditions for quail eggs, highlighting the importance of temperature control and turning frequency for achieving higher hatchability rates, minimizing deformities, and reducing mortality.

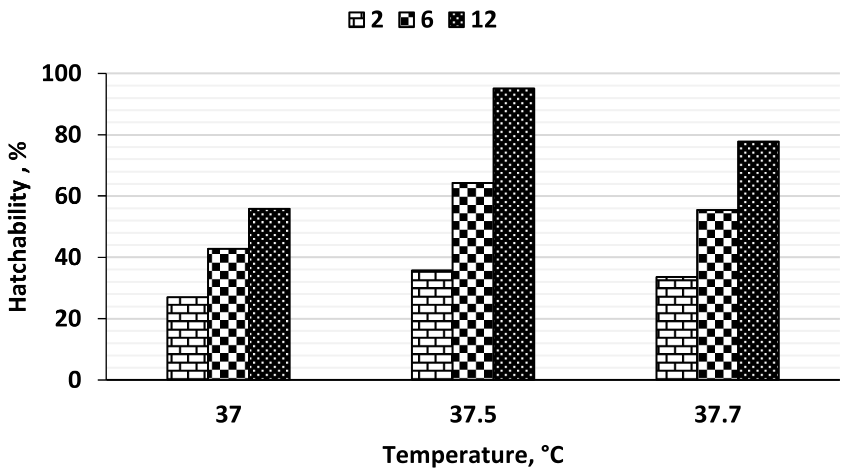


Figure 3. Effect of incubation temperature (°C) and turning time per day on the mean percentage of hatchability (%).

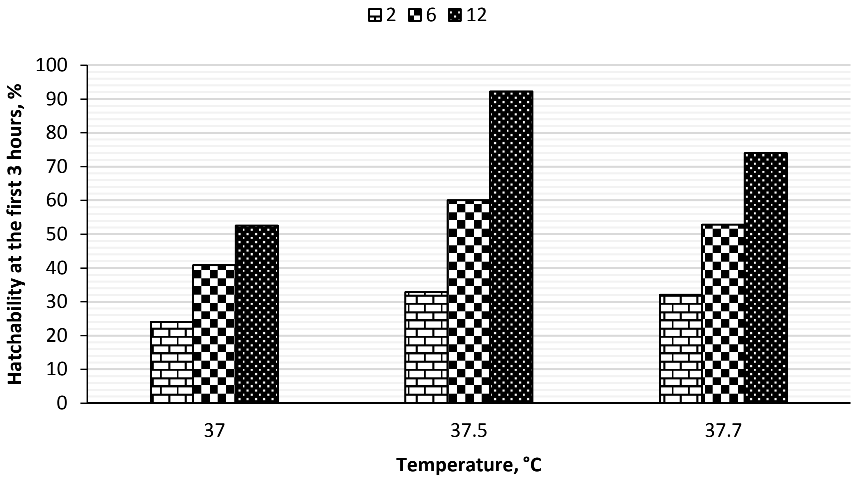


Figure 4. Effect of incubation temperature (°C) and turning time per day on the mean percentage of hatchability (%) in the first 3 hours.

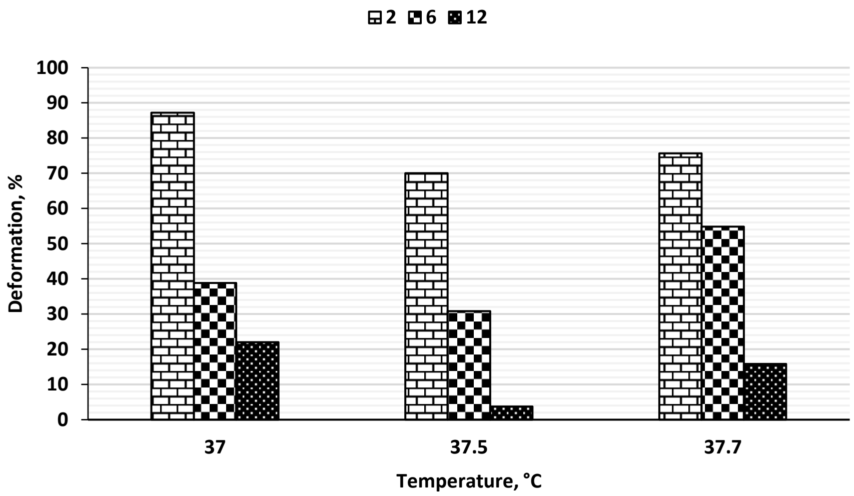


Figure 5. Effect of incubation temperature (°C) and turning time per day on the mean percentage of deformation (%).

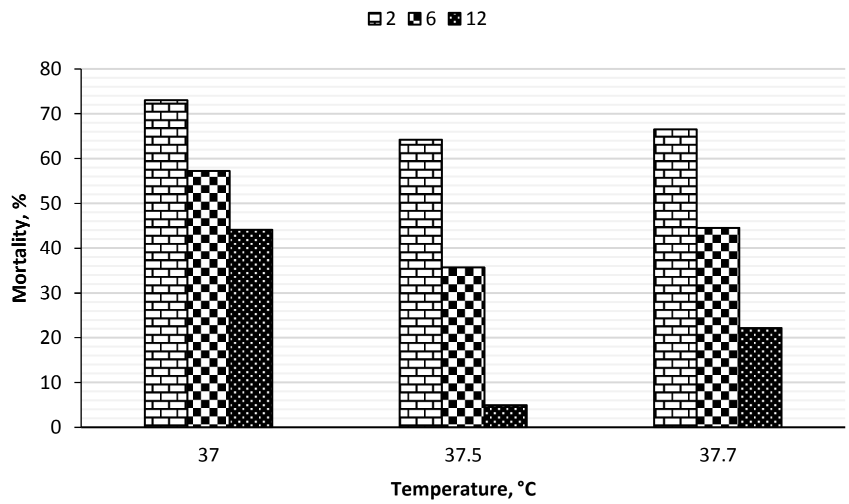


Figure 6. Effect of incubation temperature (°C) and turning time per day on the mean percentage of mortality (%).

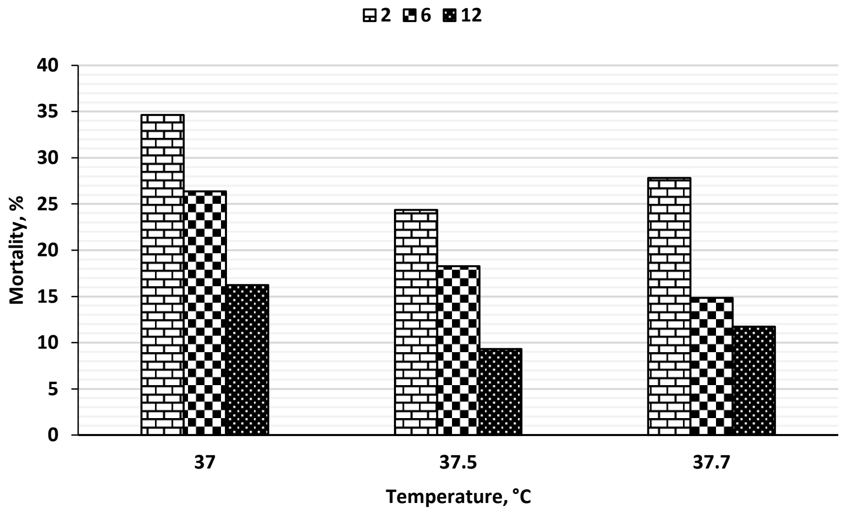


Figure 7. Effect of incubation temperature (°C) and staying period (h) on the mean percentage of mortality (%).

4. Conclusion and Recommendations

In conclusion, the study highlights the critical role of optimal incubation temperatures and turning times per day in achieving higher hatchability rates and minimizing deformities and mortality in quail eggs. The results demonstrate that hatchability decreases, deformation increases, and mortality rates increase when the incubation temperature deviates from the optimal 37.5°C. Consistency in turning the eggs, with a minimum of 12 times per day, is crucial for successful hatching and reduced mortality. Moreover, the deformation percentage is dependent on maintaining the optimal temperature, while the hatchability percentage is influenced by both temperature and the frequency of turning.

Based on the findings of this study, the following recommendations can be made:

1. Maintain an incubation temperature of 37.5°C for optimal hatchability, while avoiding temperatures lower or higher than this range.

2. Implement a turning schedule of at least 12 times per day to prevent the embryo from sticking to the shell and thus improve hatchability.

3. Ensure a longer staying period in the incubator after hatching to minimize mortality rates, as quail chicks are particularly sensitive to temperature during handling.

4. Monitor and control the incubation temperature and turning times per day rigorously to achieve consistent and optimal conditions for successful hatching.

5. Further research should be conducted to explore the impact of other factors, such as humidity and egg positioning, on hatchability, deformity rates, and mortality in quail eggs.

By implementing these recommendations, poultry farmers and hatchery operators can enhance the hatchability and overall quality of quail chicks, leading to improved production efficiency and profitability.

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Research Article

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Detection of some registered barley varieties reactions to barley leaf stripe disease

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ABSTRACT

Cereals are a significant agricultural product group with the highest cultivation area and production in Turkey. Among these cereals, barley is an important cereal used in human and animal nutrition, and the most widelycultivated plant after wheat. There are biotic and abiotic factors which affect the yield and quality parameters of barley. Of the biotic factors, barley leaf stripe (agent: *Pyrenophora graminea* (anamorph: *Drechslera graminea*) is an important fungal disease. Infections can occur in diseased seeds and in the presence of suitable environmental conditions. Hence, the use of disease-free seeds and resistant cultivars (cvs.) against this pathogen are crucial. With this in mind, this study was carried out with a highly virulent isolate of *Pyrenophora graminea*, obtained from the Disease and Pest Resistance Unit culture collection in 57 registered barley cultivars in the greenhouses of the Central Research Institute of Field Crops (TARM) in 2021. The experiments were conducted in 3 replications in a randomized block design. Of 57 registered barley cultivars 62%, 15% and 36% of these barley cultivars expressed resistance, moderate resistance, and susceptible reactions, respectively. As a result of the analysis of variance performed on the results obtained, it was concluded that the difference between the mean values of 57 varieties was statistically significant at 1% level ($P<0.01$).

1. Introduction

Barley is one of the cereal groups with the highest vegetation area and yield both in the world and in Türkiye. The production of barley in the world between 2020 and 2021 has been reported at 158 million tonnes (Anonymous 2021). According to 2020 data, barley is the second cereal, after wheat, in Türkiye in terms of yield and cultivation area. Barley is used as green hay, for malt production, and for human nutrition. It mostly grows in Central Anatolia, Southeastern Anatolia, and the Aegean Region, as well as in other parts of Türkiye (Anonymous 2021).

There are biotic and abiotic factors that affect the yield and quality of barley. The most significant biotic factor is barley stripe disease (*Pyrenophora graminea (anamorph: Drechslera graminea*) that contaminates viainfected seeds and could be damaging. Many studies across the world have also reported severe losses due to this disease (Porta-Puglia et al. 1986, Arabi et al. 2004, Karakaya et al. 2016).

The pathogen mostly develops in barley-growing areas, particularly in rainy weather conditions , and has led to a nearly 10-15% yield loss in the Central Anatolia Region (Aktaş 2001; Anonymous 2008). A symptom of this disease can be seen as yellow stripes that cover the barley leaf from bottom to tip. As the disease develops, these yellow stripes turn to brown necrotic lesions and sometimes tearing in leaves can be observed due to these necrotic areas. Dwarfing can generally be observed in diseased plants and plants may dry completely in early stages especially in dryland areas. Spikes may not appear or may have a malformation. Condia could occur abundantly on conidiophores. In the heading stage, the pathogen produces many conidia and these can infect the healthy spikes via wind. The pathogen cannot survive in crop debris, although mycelium of the pathogen can be carried via seed, hull and pericarp. When contaminated seeds are sown, the fungi/fungus will move systematically and the disease develops (Anonymous 2008).

There are various ways to control the disease such as fungicides. Even though seeds are treated with chemicals against stripe disease, during planting the disease can still be observed in low levels. Additionally the disease becomes common under suitable conditions when untreated seeds are planted over several years (Nielsen and Scheel 1997). Due to this, developing tolerant/resistant cultivars (cvs.) is crucial because it is the most efficient and environmentallyfriendly approach (Arabi and Jawhar 2005). In addition to developing cultivars, it is important to obtain knowledge about the virulence of the disease agent (Arabi and Jawhar 2012; Mokrani et al. 2012; Nielsen et al. 2002).

There are different studies that have determined various barley materials in order to explore potential candidate genotypes for breeding studies (Nielsen et al 2002; Benkorteby-Lyazıdı et al. 2018; Çelik Oğuz et al. 2017; Çelik et al. 2016; Çelik Oğuz 2019). The aim of this study is to identify the reactions of 57 registered cultivars, developed in Türkiye, using the most virulent *Pyrenophora graminea* isolate obtained from the culture collection of Disease Resistance Unit of Field Crops Central Research Institute under greenhouse conditions.

2. Materials and Methods

2.1. Materials

The materials of this study consist of 57 barley cvs. from Türkiye and a highlyvirulent isolate of *Pyrenophora graminea*. The isolate was provided from the collection of Disease Resistance Unit in Central Research Institute for Field Crops.

2.2. Methods

2.2.1. Seed ınoculation and growing the plants

The "sandwich" method, which was developed by (Mohammed and Mahmood 1976), wasapplied in this study. The isolate of *P.graminea* was developed in PDA media at 22°C until it covered the petri dishes. The seeds of each genotype were treated with 1% sodium hypochlorite (NaOCl) for 3 min in order to disinfect the surface of the seeds and then washed with sterile water. After sterilization, 20 seeds of each barley genotype were placed into half of the 10 days old fungi cultures and the other half of the same culture were folded and placed into the other half, shaped like a sandwich. After keeping the petri dish for 72 h at 22°C under light, they were incubated for 5-7 days at +4°C, depending on the seed germinations. After incubation, 20 seeds placed into PDA were planted into 16 cm diameter pots filled with a mix of sand-fertilizer-soil (1:1:3 ratio, respectively). The experiment was set according to a randomized block design with three replicates. The pots placed in the greenhouses with day and night temperatures changed between 10-22 ± 3°C.

2.2.2. Assessment of the disease

The reactions of the infected 57 cvs. were assessed 60 days after planting the soil with 1-3 scale developed by Tekauz (1983).

According to the scale;

1: Resistant (stripe infection %<5%)= R

2: Moderate Resistance (stripe infection %<5-17%)= MR

3: Susceptible (stripe infection %>17%)= S

The Duncan test analysis was performed by using *agricolae* package of R language (version 1.3).

3. Results and Discussion

The seedling reactions of fifty-seven registered cvs. were identified with a highly virulent *Pyrenophora graminea*. According to the Tekauz scale, the cultivars which had less than 5%, between 5% and 17% and more than 17% disease scores were grouped as resistant, moderate resistance and susceptible, respectively. Variance analyses shows that the difference between the mean values of 57 varieties was statistically significant at about 1% (P<0.01). The difference between the varieties was also controlled using the Duncan Test. All data is reported in Table 1. According to Table 1, Keykubad, Olgun, Akhisar 98, Sur-93, Şahin-91, Altıkat, Barış, Hevsel, Hamidiye, Çıldır 02, Erginel 90, İnce-04, Keser, Özdemir, Ünver, Bilgi-91, Sabribey, Yüksel, Çetin 2000, Zeynel Ağa, Akar, Özen, Tosunpaşa, Bozlak, Asil, Anka-06, Misket, Martı, Bolayır, Harman, Hasat, Yaprak, Sladoran, Helke, , Ocak and Yeşilköy 387 cvs. were grouped as resistance. Kıral-97, Güldeste, Ay, Cumhuriyet 50, Tarm-92, Tokak 157/37, Avcı 2002, Burakbey and Yalın were identified as moderate resistance. Additionally, susceptible cvs. were Larende, Karatay, Ayrancı, Samyeli, Kendal, Dara, Yerçil-147, Bülbül 89, Aydanhanım, Yesevi 93, Orza 96 and Cacabey.

Table 1. Results of 57 registered barley cultivars reactions tobarley leaf stripe between 2020 and 2021

No	Varieties	Mean	Result
1	Kıral-97	8e	Moderate Resistance
2	Larende	67a	Susceptible
3	Karatay 94	62ab	Susceptible
4	Ayrancı	19d	Susceptible
5	Keykubad	0f	Resistance
6	Güldeste	8e	Moderate Resistance
7	Ay	9e	Moderate Resistance
8	Olgun	0f	Resistance
9	Akhisar 98	0f	Resistance
10	Sur-93	0f	Resistance
11	Şahin-91	0f	Resistance
12	Altıkat	0f	Resistance
13	Samyeli	21d	Susceptible
14	Kendal	25d	Susceptible
15	Barış	0f	Resistance
16	Hevsel	0f	Resistance
17	Dara	19d	Susceptible
18	Hamidiye	0f	Resistance
19	Bilgi-91	0f	Resistance
20	Cumhuriyet 50	10e	Moderate Resistance
21	Çıldır 02	0f	Resistance
22	Erginel 90	0f	Resistance
23	İnce-04	0f	Resistance
24	Keser	0f	Resistance
25	Özdemir	0f	Resistance
26	Yerçil-147	21d	Susceptible
27	Ünver	0f	Resistance
28	Sabribey	0f	Resistance
29	Yüksel	0f	Resistance
30	Avcı-2002	12e	Moderate Resistance
31	Aydanhanım	67a	Susceptible
32	Bülbül 89	57b	Susceptible
33	Çetin 2000	0f	Resistance
34	Tarm-92	10e	Moderate Resistance
35	Tokak 157/37	10e	Moderate Resistance
36	Yesevi 93	25d	Susceptible
37	Zeynel Ağa	0f	Resistance
38	Akar	0f	Resistance
39	Özen	0f	Resistance
40	Burakbey	9e	Moderate Resistance
41	Yalın	9e	Moderate Resistance
42	Tosunpaşa	0f	Resistance
43	Orza 96	67a	Susceptible
44	Bozlak	0f	Resistance
45	Asil	0f	Resistance
46	Anka 06	0f	Resistance
47	Cacabey	40c	Susceptible
48	Misket	0f	Resistance
49	Martı	0f	Resistance
50	Bolayır	0f	Resistance
51	Harman	0f	Resistance
52	Hasat	0f	Resistance
53	Yaprak	0f	Resistance
54	Sladoran	0f	Resistance
55	Helke	0f	Resistance
56	Ocak	0f	Resistance
57	Yeşilköy 387	0f	Resistance

According to a study done with fifteen different cultivars using 5 different isolates, Yerçil-147 variety was scored as resistant, whereas Erginel 90, Orza 96, Çetin 2000 and Aydanhanım were found susceptible to 3 isolates. The same study revealed that Erginel 90 cvs. were resistant to an isolate obtained from Yenimahalle Ankara while Çetin 2000 showed moderate resistance (Ulus and Karkaya 2007). This study showed that Yerçil-147, Orza 96 and Aydanhanım cvs. were susceptible but Erginel 90 and Çetin 2000 cvs. were resistant.

Another study illustrated that Durusu, Balkan 96 (Igri), Çumra 2001 and Anadolu 98 cultivars reacted resistant to all thirteen barley stripe pathogen isolates while Atılır and Larende were found to be susceptible (Bayraktar and Akan 2012). It was observed in this study that Larende were also susceptible.

In astudy of23 various barley genotypes, twenty of which were barley landraces and 3 were registered varieties, were tested with 10 different isolates and Larende and Atılır expressed a susceptible response to nine isolates, but Çumra 2001 reacted resistant to all isolates (Çelik et al. 2016). This study has found similar results that Larende showed susceptibility.

Tunalı (1992) used a virulent isolate and found that Bülbül 89, Erginel 90 and Cumhuriyet 50 were resistant and Tokak 157/37 and Yerçil-147 were moderately resistant and susceptible, respectively. This study found that Tokak 157/37 and Cumhuriyet 50 were moderately resistant while and Yerçil-147 was identified as susceptible. Additionally, Bülbül-89 reacted susceptible but Erginel 90 was resistant.

Çetin et al. (1995) identified Tokak 157/37, Tarm 92, Bülbül 89, Orza 96 and Yerçil 147 as susceptible. While, Tarm 92, Bülbül 89, Orza 96 and Yerçil 147 were detected as susceptible, Tokak 157/37, were detected as a moderate resistant reaction in this study, differently.

Konak and Scharen (1994) detected Tokak 157/37 reacted as resistant. Cumhuriyet 50 exhibited resistance to an isolate but reacted to another isolate as moderately resistant. However this studywas found that Tokak 157/37 and Cumhuriyet 50 varieties showed a moderate resistance reaction.

Comparing the studies done for the last 27 years with this study, it is observed some cvs. reacted differently. Though isolates of *Pyrenophora graminea* in Turkey are thought to be homogenous genetically (Bayraktar and Akan 2012), variances in virulence degree of the isolates support the genetic diversity in *P.graminea*. Therefore, this might be the reason for the dissimilar results of the cultivars used in this study.

In a study carried out in 2004, protein profiles of 27 different isolates were described with the SDS PAGE method and a high degree of genetic diversity revealed (Arabi and Jawhar 2004). In another study, 34 different progeny were produced matching an isolate with a high virulence with a low virulent isolate in vitro and significant diversities observed among these progenies (Arabi and Jawhar 2007). Also many researchers have reported various levels of pathogenic diversity between *P.graminea* isolates (Hammouda 1988, Mohammad and Mahmood 1976; Tunalı 1992; Tunalı 1995; Ulus and Karakaya 2007; Çelik et al. 2016). Therefore, the reactions between cultivars may differ due to the diversity of isolates. However, there are limited studies done in this subject and it is important to uncover the underlying reasons forthis diversity with recent molecular techniques.

4. Conclusion

Though there are ways to control this disease, such as chemicals, the most efficient way is to develop tolerant cultivars that are environmentally friendly and less costly. Nevertheless, resistant cultivars may lose their tolerance degree against new virulent patotypes/races (Andersen et al. 2018). For this reason it is significant to survey and determine the pathogenic variation both phenotypically and genotypically andbreeding new varieties with this information. The effect of the disease on some important agricultural characters could also be investigated in further studies.

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Effect of different natural habitats on the variation in essential oil components of *Origanum onites* L.

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ABSTRACT

Origanum onites L., which is native to the Mediterranean region, is among one of the economically significant medicinal and aromatic plants that are not only gathered in the wild, but also cultivated in our country. The purpose of this study was to determine how the region in which *Origanum onites* grows affects the amount of essential oil and essential oil components in the plant's flowers and leaves. In this context, the effect of the plant's growing location on the essential oil content and essential oil components of the flowers and leaves of the *Origanum onites*, which grows naturally between 0-100 m in the Serik-Aksu, Demre, and Kaş regions of Antalya, was investigated together with the soil properties. The essential oils were extracted from the plant samples' leaves and flowers using the hydrodistillation method. The analysis of essential oils was done using gas chromatography-mass spectrometry (GC-MS) systems. Soil samples were analyzed for their pH, EC, $CaCO_3$, texture, organic matter, total N, available P, and K values. The organic matter and exchangeable potassium contents of the soils, as well as the content of essential oil in the flowers and leaves of the plants, were found to increase gradually towards the west of Antalya. It has been demonstrated that the amounts of essential oil components of the plants varied depending on the region in each of the three different study locations.

1. Introduction

The genus *Origanum* L. (*Lamiaceae*) with 21 species (13 endemics out of 24 taxa) and 13 hybrid taxa has a wide distribution in Turkey flora (Arabaci et al. 2020). Species in *Origanum* are plants that have commercial prominence and are exported in substantial amounts. Its cultivation is widely done along the shores of the Aegean and the Western Mediterranean (Balıkesir, İzmir, Aydın, Muğla, Antalya). Turkey leads exportation worldwide, with a 19957 hectares cultivation area and 21174 tons of production per year in 2021–(TUIK 2022). *Origanum onites* L. which is colloquially known as İzmir kekiği, bilyalı kekik, eşek kekiği as regional names, and is called Turkish thyme (Türk kekiği) in Europe, has the largest thyme export share (approximately 80%) in the world (TRGM 2020).

Since antiquity, *O. onites* L. has been used as a spice, flavoring, herbal tea, and essential oil. The essential oil in the plant's leaves and flowers is the most important secondary metabolite, and the quantity of essential oil varies from 0.2 percent to 8.0 percent (Can et al. 2021). Carvacrol, thymol, linalool, ɣ-terpinene, α-terpinene, terpinen-4-ol, cymene, β-bisabolene, α-pinene, borneol, myrcene, α-thujene, β-caryophyllene, β-pinene, camphene, α-terpineol, caryophyllene oxide, terpinene, limonene and α-phellendran are the primary components of *O. onites* essential oil (Demirci et al. 2004; Tepe et al. 2016; Ozdemir et al. 2018). Essential oil extracted from *O. onites* possesses features such as antibacterial and antifungal (Vanti et al. 2021), antimicrobial (Tepe et al. 2016), antiviral, insecticidal (Ayvaz et al. 2010), anti-inflammatory (Aykac et al. 2020), anticancer (Spyridopoulou et al. 2019), analgesic activities (Aydın et al. 1996) and a source of natural antioxidant (Ozdemir et al. 2018). The composition and quantity of essential oils extracted from medicinal and aromatic plants may vary based on the kind of plant, plant organs, production technique, harvest time, drying process, geographical structure, and climate of the location in which they are cultivated (Kpoviessi et al 2016, Ozer et al 2018, Masoudi 2018, Mehalaine and Çencuni 2021).

In this study, the effect of the location where the plant grows on the essential oil yield and essential oil components in the flowers and leaves of the *O. onites* plant, which grows naturally in the Antalya districts of Serik-Aksu, Demre, and Kaş, as well as the soil properties was researched.

2. Materials and Methods

This research was carried out in June 2011 on plant and soil samples in Serik-Aksu, Demre and Kaş districts where *Origanum onites* naturally spreads. Samples were taken during the plant's full blooming periods when the essential oil components of the plant are at their highest. Between 0-100 meter altitude, 10 from Serik-Aksu district, 10 from Demre district, with the inclusion of 10 from Kaş district, a total of 30 soil and 30 plant samples were taken. The GPS coordinates were determined, and the locations of the samples taken are shown in Figure 1.

2.1. Soil analysis

Soil samples were taken to define edaphic characteristics from a depth of 0-30 cm by considering *O. onites'* root system. The samples were sifted through a 2 mm sieve after being dehydrated in room conditions. Suspension of soil samples' pH and EC at 1:2.5 soil: water mixed rates were defined with a WTW pH meter (Jackson 1967) and WT-720 EC meter. The content of $CaCO_3$ was measured by the Scheibler calcimeter (Çağlar 1949). The analysis of soil texture was defined with the hydrometer method (Black 1957). The organic matter content was determined according to the modified Walkley-Black method (Black 1965). The total amount of nitrogen in the soil was defined using the modified Kjeldahl method (Kacar 1995), the amounts of available phosphorus were defined using the Olsen method (Olsen and Sommers 1982), and the contents of exchangeable potassium were defined with the 1N Amonyum Asetat method (Kacar 1995). An ICP-OES Perkin Elmer 7000 DV device was used for the analysis of phosphorus and potassium.. While the obtained values were classified, the soil pH was determined according to Kellog (1952) and the electrical conductivity was determined by the U.S. According to Soil Survey Staff (1951), lime levels according to Evliya (1964), texture classification according to Black (1957), organic matter contents according to Black (1965), total nitrogen according to Loue (1968), available phosphorus was determined according to Olsen and Sommers (1982) and exchangeable potassium according to Pizer (1967).

2.2. Essential oil amount

Plant samples taken from three different distribution areas were dried in the shade at room temperature. Essential oils of dried flower and leaf samples were obtained by distillation in a Clevenger type hydro-distillation device. The method described in the ICS 11.120.10.67, 120.10 (TSE 1991) report of the Turkish Standards Institute was used to determine the essential oil content in dried leaf and flower samples. 20±0.001 g of plant materials were mixed with 300 ml of distilled water, and the samples were then distilled in the Neoclevenger apparatus for five hours. The amounts of essential oils obtained were measured in ml and their percentages (v w^{-1}) after taking their average were calculated.

2.3. GC-MS Analysis

O. onites' essential oil component rates (%) that were obtained from dried plant materials were obtained with an Agilent 7890A 5975C GC-MS device. As GC-MS capillary columns HP Innowax Capillar columns 60.0 m X 0.25 mm X 0.25 µm were used. Capillary column heat program: 60ºC It was increased by 20ºC in 10 minutes to 250ºC and kept at 250ºC for 8 minutes. Injection block's heat 250ºC, Rate of Split: 50:1, Volume of Injection: 1 µL, Carrier Gas: Helium, Rate of Flow: 1 mL min^{-1}. In defining essential oil components, Wiley, Nist and Flovor mass spectral library data were used.

2.4. Statistical analysis

In this study, a licensed SPSS 23 statistical program was used for obtaining digital data. An analysis of variance (ANOVA) and a Duncan test were applied to the data of the study.

3. Results and Discussion

3.1. Soil properties

The pH of the soils ranged from 6.84 to 7.98, with 96.67 percent exhibiting mildly alkaline and alkaline responses. The $CaCO_3$ level of the samples ranged from 1.75 to 34.30 percent and was determined to be in generally the category of high to very high calcareous soils. The EC analysis results were between 0.14-0.91 dS m^{-1} and it was determined that all of the soils were salt-free. Despite the fact that soil textures vary greatly, 93.3 percent of the soil samples are loamy. The quantity of organic matter in the soils varies between 0.41 and 11.80 percent, according to the findings. The quantity of organic materials rose

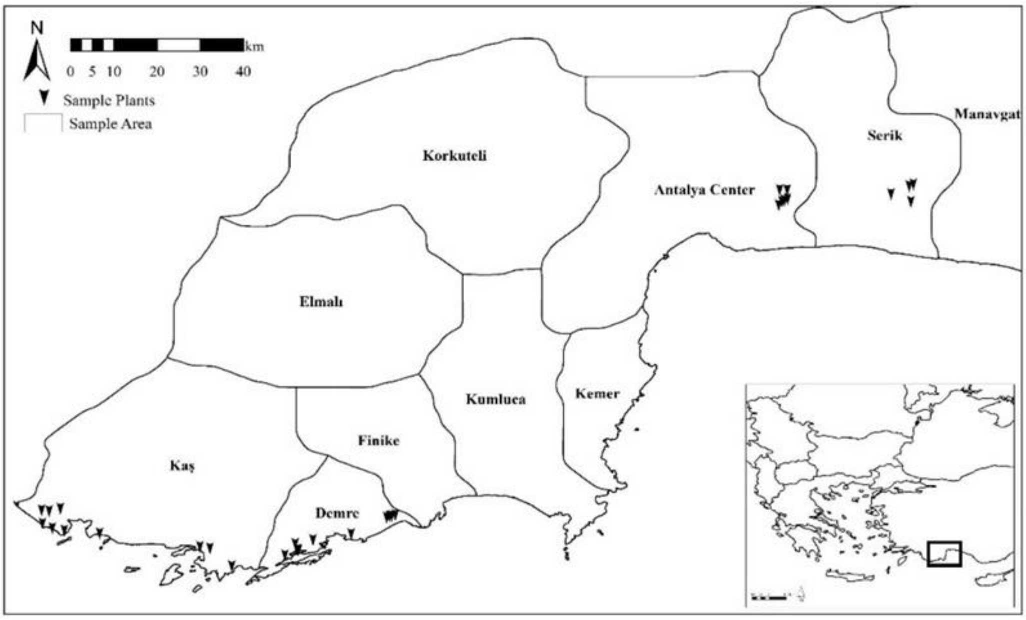

Figure 1. Location of the study area and sampling points.

from Serik-Aksu to Kaş. As shown in Table 1, the soil sample from Kaş had the maximum quantity of organic matter (8.52 percent), which is statistically significant at the 5 percent level.

According to Thun (1955)'s classification of the organic matter content of soil samples, all of the soils from Kaş and 60% of the soils from Demre are categorized as highly humus soil. In Serik-Aksu, 70% of the soil is classified as humus-poor or low-humus.

Soils with nitrogen contents ranging from 0.06 to 1.28 percent (on average 0.48 percent), phosphorus contents ranging from 44.71 to 68.95 mg kg^{-1} (on average 55.78 mg kg^{-1}), and potassium contents ranging from 0.19 to 2.69 me 100 g^{-1} (on average 0.77 me 100 g^{-1}) were found. In a general assessment of the nitrogen, phosphorus, and potassium contents of the studied soils, it was established that 90 percent are in good condition in terms of nitrogen content, 100 percent are high in terms of phosphorus content, and 83.33 percent are adequate in terms of potassium content. The phosphorus content in soil samples from Demre (61.39 mg kg^{-1} P) and the potassium content in soil samples from Kaş (1.14 me 100 g^{-1} K) were higher than in other locations, and these differences were statistically significant at the 1% level (Table 1).

Table 1. Chemical and physical properties of the soils

Soil parameters	Critical level /Mean value	Evaluation	Serik- Aksu		Demre		Kaş		Total	
			N[1]	%	N	%	N	%	N	%
pH	6.6-7.3	Neutral	-	-	1	10	-	-	1	3.33
	7.4-7.8	Less alkaline	6	60	8	80	10	100	24	80
	7.9-8.4	Alkaline	4	40	1	10	-	-	5	16.67
Total $CaCO_3$(%)	0-2.5	Low	1	10	-		-	-	1	3.33
	2.6-5.0	Lime	2	20	5	50	3	30	10	33.34
	5.1-10.0	High	1	10	1	10	2	20	4	13.33
	10.1-20.0	Very high	-	-	1	10	2	20	3	10
	20.0<	Extremely high	6	60	3	30	3	30	12	40
EC (dS m^{-1})	2.5>	Saltless	10	100	10	100	10	100	30	100
Structure		Sandy Loam	4	40	3	30	2	20	9	30
		Loam	1	10	1	10	2	20	4	13.33
		Sandy-Clay Loam	4	40	-	-	2	20	6	20
		Clay Loam	1	10	4	40	4	40	9	30
		Clay	-	-	2	20	-	-	2	6.67
Organic matter (%)	0-2	Very low	4	40	2	20	-	-	6	20
	2-5	Low	3	30	2	20	-	-	5	16.67
	>4.0	High	3	30	6	60	10	100	19	63.33
Total N (%)	0.070>	Very low	1	10	-	-	-	-	1	3.33
	0.09-0.11	Medium	1	10	1	10	-	-	2	6.67
	0.11-0.13	High	2	10	1	10	-	-	3	10
	0.13<	Very high	6	60	8	80	10	100	24	80
Available P (mg kg^{-1})	>10	High	10	100	10	100	10	100	30	100
Exchangeable K (Meq 100g^{-1})	0.26>	Very low	-	-	1	10	-	-	1	3.33
	0.26-0.39	Low	3	30	1	10			4	13.33
	0.39-0.51	Medium	3	30	2	20			5	16.67
	0.51-0.64	Good	3	30	1	10	2	20	6	20
	0.64-0.82	High	1	10	1	10	4	40	6	20
	0.82<	Very high	-	-	4	40	4	40	8	26.67
									Anova	
pH			7.84[2]		7.60		7.62		ns	
$CaCO_3$(%)			20.12		12.97		12.78		ns	
EC (dS m^{-1})			0.24		0.27		0.24		ns	
Structure		Sand (%)	55.68		42.14		42.84		ns	
		Clay (%)	19.23		30.15		24.40		ns	
		Silt (%)	25.03		27.71		32.76		ns	
Organic matter (%)			3.59 b		4.89 b		8.52 a		*	
Total N (%)			0.44		0.37		0.62		ns	
Available P (mg kg^{-1})			53.45		61.30		52.60		**	
Exchangeable K (Meq 100 g^{-1})			0.50 b		0.67 b		1.14 a		**	

[1]: Number of samples, [2]: Means with the same letter are not significantly different from each other (*P*>0.05 ANOVA followed by Duncan's multiple range tests).
*, **: Statistically significant at 0.05 and 0.01 probability levels, respectively. The letters represent different groups at 0.05 probability level. ns: Not significant.

3.2. Amount of plants' essential oil and components

The essential oil content of *O. onites* leaves and flowers range from 1.21% to 6.55 % (v w^{-1}), 2.61% to 8.13% (v w^{-1}), with an average of 3.09% and 5.79% (v w^{-1}), respectively. In every three locations where the sampling was made, the content of essential oil in flowers was higher than in leaves (Table 2). The essential oil content in the flowers is substantially greater than in the leaves because the blooms have more glandular hairs (Werker et al. 1985; Karamanos and Sotiropoulou 2013). Kacar et al. (2010) determined that the average essential oil content of *O. onites* leaves and flowers is between 1.88 and 3.06 percent (v w^{-1}) and 2.85 and 4.08 percent (v w^{-1}), respectively. In his research on *O. onites*, Özer (2020) estimated the essential oil content to be 1.75 percent (v w^{-1}) in the leaves and 4.25 percent (v w^{-1}) in the flowers. Our research determined that the average essential oil content of the leaves and flowers of *O. onites* was greater than that of the other two studies. The differences in results among studies can be explained by the physiological variation of the plant, the time, the harvest, and environmental conditions such as the geographical location of the place where the plant grows, climate, and soil characteristics (Öner and Sonkaya 2020; Efendi et al. 2021; Mehalaine and Çencuni 2021).

As seen in Figure 2, it was determined that the amount of essential oil in the leaves and flowers of the plants increased as the locations go from Serik-Aksu towards Kaş. While the change in the amount of essential oil in the leaves was statistically insignificant, the change in the amount of essential oil contained in the flowers was statistically significant at the 5% level. The highest amount of essential oil contained in the flowers was obtained from plants collected from Kaş, with 6.58%, followed by Demre with 5.38% and Serik-Aksu with 4.64.

Components of *O. onites*' essential oil define its quality and aroma. In leaves and flowers, that were collected from the research areas, a minimum of 14 and a maximum of 43 essential oil components have been defined in leaves and flowers that were collected from the research areas. In a statistical analysis of plants' essential oil components, 11 common components that are contained by leaf samples that were taken from each of three locations and 10 common components that are contained by flowers were assessed. Data for *O. onites*' essential oil components in its leaves and flowers is presented in Table 2. Carvacrol was found to be the most abundant component of essential oils in both leaves and flowers from all three places, followed by thymol in Serik-Aksu and Kaş, and cymene in Demre. The effects of research areas on the carvacrol and thymol parts of plant essential oils did not differ in a way that was statistically significant.

Among the essential oil components found in the leaves, cymene ranges from 0.32 to 10.50 percent, with an average of 4.82 percent, linalool ranges from 0.27 to 12.29 percent, with an average of 3.12 percent, terpinene-4-ol ranges from 0.18 to 1.35 percent, with an average of 0.85 percent, and β -caryophyllene ranges from 0.57 to 2.56 percent, with an average of 1.39 percent. In previous studies on the essential oil components that the leaves of *O. onites* contained, average rates of between 3.96 and 8.76 percent cymene, between 0.20 and 8.39 percent linalool, between 0.46 and 2.09 percent terpinene-4-ol, and between 0.49 and 1.52 percent β -caryophyllene were reported (Copur et al. 2010; Tonk et al. 2010; Katar and Katar 2020), and the average values of essential oil.

The effect of plant location on the essential oil components cymene, linalool, terpinen-4-ol, and -caryophyllene in the leaves of *O. onites* has been statistically determined to be significant. Serik-Aksu plants have the highest levels of cymene (6.38 percent), terpinene-4-ol (1.06 percent), and -caryophyllene (0.77 percent) in their leaf essential oil components. Linalool content in leaves' essential oil of 6.41% has been defined mostly in samples from Kaş. Among the essential oil components contained in the flowers, β-myrcene between 0.24-1.09%, on average, 0.69%, gamma-terpinene between 0.01-8.17%, on average 2.34%, linalool between 0.34-18.56%, on average 3.57%, and terpinen-4-ol between 0.19-1.85%, on an average 0.78% were identified. In terms of essential oil components in flowers, while the samples taken from Serik-Aksu had the highest amounts of β-myrcene (0.81%), gamma-terpinene (3.49%), and terpinen-4-ol (0.91%), The highest linalool content (6.07%) was detected in the samples from Kaş. These differences in research areas are statistically significant.

Table 2. Average values of essential oil ratios and components in the leaves and flowers of *Origanum onites* L. plants

RI	Essential oil components	SERİK-AKSU (1)			DEMRE (2)			KAŞ (3)			1X2X3	1X2X3
		Leaf	Flower	LXF	Leaf	Flower	LXF	Leaf	Flower	LXF	Leaf	Flower
1155	β-myrcene	0.55[1]B	0.81 A***a***	*	0.44 B	0.76 A***a***	**	0.44	0.50 ***b***	*ns*	ns	*****
1238	γ-terpinene	-	3.49 ***a***	-	-	1.20 ***b***	-	-	1.18 ***b***	-	-	******
1264	Cymene	6.38 Aa	3.25 B	**	4.89 Aba	2.65 B	*	3.19 b	2.06	*ns*	*	*ns*
1534	Linalool	2.23 b	2.40 *b*	*ns*	0.71 b	1.06 *b*	*ns*	6.41 a	6.07 *a*	*ns*	**	*
1543	Cis sabinene hydarate	0.70 A	0.39 B	**	0.62 A	0.32 B	**	0.57 A	0.29 B	*	ns	*ns*
1597	Terpinene-4-ol	1.06 a	0.91 ***a***	*ns*	0.88 a	0.81 ***ab***	*ns*	0.63 b	0.56 ***b***	*ns*	**	*****
1587	β-caryophyllene	1.77 Aa	1.23 B	**	1.18 b	0.89	*ns*	1.23 b	0.97	*ns*	*	*ns*
1671	α-humulen	0.41	-	-	0.32	-	-	0.28	-	-	ns	-
1694	Borneol	1.04 A	0.65 B	*	1.02	0.77	*ns*	1.21	0.74	*ns*	ns	*ns*
1995	Caryophyllene oxide	0.73	-	-	0.69	-		0.53	-	-	ns	-
2223	Thymol	9.26	5.69	*ns*	0.95	0.67	*ns*	7.78	10.38	*ns*	ns	*ns*
2264	Carvacrol	62.72	76.19	*ns*	78.77 B	85.05 A	**	68.64	73.68	*ns*	ns	*ns*
	Total number of components	35.60 Aa	20.70 B***a***	**	32.40 Aab	22.20 B***a***	**	27.7 Ab	17.40 B***b***	**	**	*****
	Essential oil ratios (%)	2.77 B	5.16 A *b*	**	3.04 B	5.56 *ab*	**	3.46 B	6.64 A*a*	**	ns	*

[1]: Means with the same letter are not significantly different from each other *P*>0.05 ANOVA followed by Duncan's multiple range tests.
*, **: Statistically significant at 0.05 and 0.01 probability levels, respectively. The letters represent different groups at 0.05 probability level. ns: Not significant.

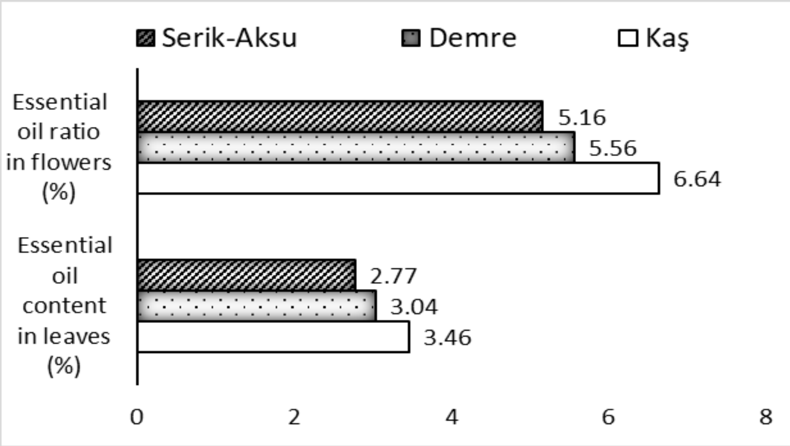

Figure 2. Essential oil ratio of flowers and leaf samples.

When the essential oil components detected in the leaves and flowers of the samples taken from all three locations were evaluated, the amount of cis-sabinene-hydarate was found to be statistically higher in the leaves. In terms of essential oil component numbers, leaves contained more components than flowers and this situation was found to be statistically significant (P<0.001).

The amounts of cymene in the essential oils of the leaves of the plants collected from Demre, and the amounts of β-myrcene and carvacrol in the essential oils of the flowers were found to be high. Cymene, β-caryophyllene and Borneol content were detected to be high in the essential oils of the leaves of the plants collected from Serik-Aksu, while the content of β-myrcene was detected to be higher in the flowers.

According to Kaçar et al. (2006) borneol, from components of *O. onites* essential oil, has been reported more in leaves than in flowers, and carvacrol has been reported more in flowers, and the results are similar to our study. As in another survey that compares essential oil components in leaves and flowers of *O.onites*, the rates of cymene, cis-sabinene hydarate and carvacrol in leaves have been defined higher (Özer 2020). In our survey, cis-sabinene hydarate and carvacrol content weredefined higher in flowers. The situation can be explained by the area's environmental conditions that surveys were conducted in, collection times (ontogenetic and diurnal variabilities), drying, and different analysis methods.

4. Conclusion

In this survey, soil and plant characteristics of *O. onites* L. that grows naturally in Serik-Aksu, Demre, and Kaş locations of Antalya, at an altitude of 0-100 m, are presented. In the meantime, the contribution of plant parts such as leaves and flowers to *O. onites* essential oil, which are used in many fields such as food, chemistry, and pharmaceutical industries, were investigated. The essential oil extracted from flowers is significantly higher. It was observed that, Carvacrol and β-myrcene from essential oil components are high in flowers' essential oils, and cymene, cis-sabinene hydarate, terpinen-4-ol, β-caryophyllene and borneol were high in leaves' essential oils.

In the survey areas, organic matter and potassium content in soils that *O. onites* plant grows have shown a regular and significant increase from the middle regions of Antalya to the west regions, and the highest rates of organic matter and potassium amounts in soil samples were observed in sampling that was done in Kaş. In a similar way, the amount of essential oil in plants' flowers and leaves increased as the location goes to the west of Antalya as well, and the highest amount of essential oil was defined in plants that were collected from Kaş. When all these locations are compared, the Kaş district stands out in terms of soil characteristics and plant essential oil amounts. If production is going to be dependent on the essential oil yield of the *Origanum onites* plant, slightly alkaline, loamy soils with high organic matter may be favored.

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