International Journal of
Agriculture, Environment and Food Sciences
e-ISSN: 2618-5946 https://dergipark.org.tr/jaefs

DOI: https://doi.org/10.31015/2025.2.35 Int. J. Agric. Environ. Food Sci. 2025; 9 (2): 617-626

Investigation of Agronomic and Physiological Performances of Different Peanuts (*Arachis hypogaea* L.) Cultivars in Denizli Ecology

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Article History
Received: May 1, 2025
Accepted: June 23, 2025
Published Online: June 26, 2025

Article Info
Type: Research Article
Subject: Agronomy

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Available at
https://dergipark.org.tr/jaefs/issue/91914/1688788

Abstract

In this study, agronomic, morphological, and physiological characteristics of 10 different peanut (*A. hypogaea* L.) cultivars were comparatively examined. Significant differences were detected among cultivars in terms of yield, pod and seed characteristics, shelling ratio, chlorophyll content, leaf area index, and oil content. The 'Florispan' cultivar had the highest yield (485.24 kg da^{-1}), while the 'Halisbey' cultivar stood out with both high yield (476.91 kg da^{-1}) and the highest oil content (57.28%). Correlation analysis showed a positive relationship between yield and leaf area index during flowering (r=0.21), and a negative relationship between yield and first-quality pod ratio (r=-0.31). Additionally, very strong positive correlations were found between 100-pod weight and 100-seed weight (r=0.91), and between oil content and chlorophyll b content during pod formation (r=0.59). Cluster analysis divided the cultivars into two main groups: Group X (Florispan, Sultan, Çom, Gazipaşa, Halisbey) included yield-focused cultivars, while Group Y (Masal, Georgia Green, Osmaniye-2005, Rigel, NC-7) contained quality-focused cultivars. Similarly, the examined characteristics were divided into two main clusters; Cluster A included yield and morphological characteristics, while Cluster B grouped physiological characteristics and oil content. Our findings emphasize that peanut cultivar selection should be made according to production purpose and highlight the importance of considering physiological characteristics' effects on yield and quality in breeding programs.

Keywords: Peanut (*A. hypogaea* L.), Yield, Correlation

Cite this article as: Beycioglu, T., Killi, F. (2025). Investigation of Agronomic and Physiological Performances of Different Peanuts (*Arachis hypogaea* L.) Cultivars in Denizli Ecology. International Journal of Agriculture, Environment and Food Sciences, 9 (2): 617-626. https://doi.org/10.31015/2025.2.35

INTRODUCTION

The origin, distribution, and genetic diversity center of peanut has been determined as South America through comprehensive research. It has been cultivated in South America since 500-750 BC and utilized as a food source (Arıoğlu, 2014). Peanut (*A. hypogea* L.), classified within the Fabaceae family, contains 20-30% protein, 18-20% carbohydrates, and 45-55% oil in its seeds (Anonymous, 2018). Peanut is a rich source of edible oil (47-54%), high-quality protein (22-30%), starch (6-24%), cellulose (1-2%), minerals (2-3%), and calories (5-6%) (Patel et al., 2018). It has a distinct importance among oilseeds due to its various consumption and utilization methods. It can be used for both edible oil and confectionery purposes. Peanut kernels are consumed raw, boiled, roasted, or fried, and are also used in various culinary preparations such as peanut butter, peanut milk, and chocolates (Patel et al., 2018).

Many researchers have examined in detail the basic characteristics that form yield and quality in various species and cultivars, and how the complex interactions between these characteristics determine the quantity and quality of the final product (Aydoğan and Soylu, 2017). Therefore, understanding these characteristics is crucial for the selection and improvement of cultivars for effective yield enhancement. Hence, it is important to understand the relationships between yield and its associated component characters. Correlation analysis measures the mutual relationship between a pair of variables independent of other variables considered (Owen & Jones 1977). Peanut is an unpredictable crop due to its underground pod development. Direct selection for improving yield in peanut

may be inadequate. Knowledge of the degree of variability and relationship among characters contributing to yield and their relative contributions to yield is necessary for developing high-yielding genotypes in peanut (Thakur et al., 2013).

Determining the interactions of physiological processes occurring in plants with environmental factors in their natural development environments and the scope of these interactions provides significant advantages in terms of agricultural production management. Remedial interventions applied in the ecological conditions where plants are grown cause significant changes in physiological activities, especially in terms of quantitative parameters. When these physiological functions develop in the desired direction, both yield increase and positive progress in quality parameters can be observed in plant production (Tunalı et al., 2012). In this context, integrated evaluation of agronomic characteristics such as yield, hundred-seed weight, hundred-pod weight, shelling ratio, and physiological parameters such as total chlorophyll, chlorophyll a, chlorophyll b, and leaf area index in peanut is of great importance for both optimizing yield potential and increasing adaptation capability to changing environmental conditions.

The objectives of this study were to (1) comprehensively evaluate the agronomic, morphological, and physiological characteristics of 10 different peanut (*A. hypogaea* L.) cultivars as selection criteria for breeding programs, (2) determine the variation among cultivars, and (3) reveal the relationships between these characteristics through multivariate analyses.

MATERIALS AND METHODS

Plant Material and Experimental Area

The experiment was established in the main crop conditions of Çal district, Denizli province, during the 2024 peanut planting season. The 10 different peanut cultivars used in the research were obtained from the Osmaniye Oilseeds Research Institute Directorate. The peanut cultivars used as material in the study, their market types, origins, and growth forms are given in Table 1.

Table 1. Market type, origin and growth forms of cultivars

Cultivars	Market type	Origin	Growth Forms
Çom	Virginia	Türkiye	Semi-spreading
Florispan	Spanish	Türkiye	Erect
Gazipaşa	Virginia	Türkiye	Semi-spreading
Georgia Green	Runner	USA	Erect
Halisbey	Virginia	Türkiye	Semi-spreading
Masal	Virginia	Türkiye	Semi-spreading
NC-7	Virginia	USA	Semi-spreading
Osmaniye-2005	Virginia	Türkiye	Semi-spreading
Rigel	Virginia	Türkiye	Semi-spreading
Sultan	Virginia	Türkiye	Semi-spreading

The soil analysis results of the Denizli-Çal region showed an electrical conductivity (EC) value of 450 µS/cm, indicating low-medium soil salinity. The soil pH value was determined as 8.3, showing that the soil has an alkaline character. The lime content was quite high at 25.77%, indicating a calcareous soil structure. Among macronutrients, potassium (K) level was 365 mg kg^{-1}, and phosphorus (P) level was 26.37 mg kg^{-1}. These values indicate that potassium and phosphorus are present at sufficient levels in the soil. However, it should be considered that the high pH value may limit phosphorus uptake by plants. The organic matter (O.M) content of the soil was measured as 1.17%, indicating a low level. Among microelements, copper (Cu) level was 1.7 mg kg^{-1}, and manganese (Mn) level was 11.4 mg kg^{-1}, which are considered sufficient levels (Lindsay and Norvell, 1978). In contrast, iron (Fe) level was measured as 5.4 mg kg^{-1} and zinc (Zn) level as 0.4 mg kg^{-1}, showing that these elements are at low levels (Table 2).

Table 2. Results of soil analysis (0-30 cm depth) of the research area

Location	EC us (µS/cm)	pH	Lime (%)	K (mg kg^{-1})	P (mg kg^{-1})	O.M (%)	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})
Denizli-Çal	450	8.3	25.77	365	26.37	1.17%	1.7	5.4	0.4	11.4

The experiment was conducted in 2024 at the Research and Application Center of the Faculty of Agriculture, Pamukkale University, in Çal district, Denizli. Climate data for the main crop growing season for Denizli-Çal conditions are given in Table 3.

Table 3. 2024 years precipitation, average temperature and relative humidity data for the experimental area (April-October average during the main crop growing season).

2024 Year	A.Precipitation (mm/kg)	A.Temperature (°C)	A.Relative Humidity (%)
April	32.1	16,0	51.1
May	42.5	16.6	58.7
June	10.2	26.8	36.1
July	51.3	26.4	44.6
August	30.3	26.2	37.6
September	0.2	20.9	50.5
October	5.6	15.0	48.8
Total	172.2	-	-

The average rainfall in the growing season of 2024 varied between 0.2-51.3 mm, with the highest rainfall occurring in July. In addition, while the average temperature value was 15-26.8 ºC, the highest temperature data was obtained during the vegetative period. The highest average relative humidity was recorded in May (58.7%) (Table 3) (Anonymous, 2025).

Method

The Research and Application Center of the Faculty of Agriculture, Pamukkale University, in Çal District, Denizli, is located at coordinates 38°05'57" north latitude and 29°25'04" east longitude in the Aegean Region. The study was carried out according to the randomized block design with 3 replications. The total experimental area was 588 m², with plot dimensions of 2.8 m × 5.0 m (14 m²), with 10 plots in each block and each plot consisting of 4 rows of plants. Before planting, the row spacing was 70 cm, and 132.0 seeds were planted per plot manually in furrows opened with a marker at a depth of 6-7 cm. The distance between blocks in the experiment was arranged as 3 m. Just before planting, 30 kg/da of Diammonium phosphate (18% N, 46% P_2O_5) fertilizer was applied and mixed into the soil. After planting, 15 kg da^{-1} of Urea (46% N) fertilizer was applied as top dressing. Additionally, all maintenance operations (weed, disease and pest control, and irrigation) were carried out throughout the growing season. Harvesting was done manually by pulling the plants in the plots and leaving them upside down to dry. Threshing was performed manually when the plant leaves turned brown and the above-ground parts dried.

In this study, a total of 16 characters including yield, one hundred pod weight, one hundred seed weight, shelling ratio, number of pods per plant, first quality pod rate, second quality pod rate, leaf area index during flowering period, total chlorophyll amount during flowering period, chlorophyll a during flowering ,chlorophyll b during flowering, leaf area index during pod period ,total chlorophyll in pod stage, chlorophyll a in pod period, chlorophyll b in pod period and oil content were analyzed (Beycioglu, 2022).

Total chlorophyll and leaf area indices were measured before harvest during the 50% flowering and pod formation stages. Chlorophyll measurements were made with a Falker brand CFL260 model chlorophyll meter during the 50% flowering period and pod formation stages. Leaf Area Index was provided by measurements made on one leaf of each plant during the same periods. Measurements were performed with a BLAM-2 Portable Leaf Area Meter.

Statistical Analysis

The experiment was established on April 28, 2024, according to the Randomized Complete Block Design with three replications. All statistical analyses of the data obtained in the study were performed using the R programming language and statistical computing environment (R Core Team, 2024). Descriptive statistics (mean, standard deviation, minimum and maximum values) were calculated for all agronomic, morphological, and physiological characteristics of peanut cultivars. One-way analysis of variance (ANOVA) was applied to determine whether there were statistically significant differences among cultivars in terms of measured characteristics. For characteristics where ANOVA results were found to be significant ($p<0.05$), Tukey's Multiple Comparison Test (Tukey's HSD) was used as a post-hoc analysis to determine which cultivar means differed from each other. Basic statistical functions of R or packages for agricultural research such as agricolae were used for these analyses (Mendiburu, 2023). Pearson correlation analysis was performed to evaluate the direction and strength of linear relationships between different characteristics examined. Correlation coefficients (r) were calculated and their statistical significance was tested ($p<0.05$). The corrplot package was used for visualization of correlation matrices (Wei & Simko, 2021). Hierarchical cluster analysis was performed using common methods such as Euclidean distance and Ward's method to visualize and group the similarities of cultivars according to measured characteristics. The analysis results were visualized with a heat map containing dendrograms for cultivars and characteristics using ggplot2 (Wickham, 2016) packages.

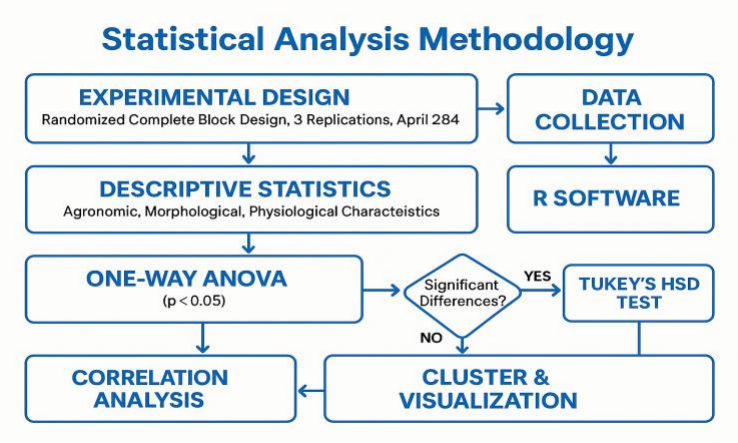

Figure 1. Statistical Analysis Methodology Flowchart

RESULTS AND DISCUSSION

Descriptive statistics of various agronomic and physiological characteristics of peanut (*Arachis hypogaea* L.) are given in Table 4. When the table is examined, yield per decare varies between 341.20-485.24 kg da^{-1}, with an average of 407.56 kg da^{-1}. The coefficient of variation of 12.15% for yield indicates a moderate yield variability among peanut genotypes. The average 100-pod weight is 197.50 g, with a high coefficient of variation of 22.81%, indicating significant differences in pod size among different peanut cultivars/lines. The hundred-seed weight has an average of 88.94 g with one of the highest coefficients of variation at 25.98%, suggesting that seed size could be a suitable criterion for selection. The shelling ratio is an important quality parameter for peanut with an average of 62.15% and shows a relatively low coefficient of variation of 9.62%. Arıoğlu et al. (2018) reported that shelling ratio is one of the most important quality parameters determining economic value in peanut. The number of pods per plant averages 26.58, with a coefficient of variation of 18.69%, making it an important variable among yield components. Canavar and Kaynak (2013) stated that the number of pods per plant is one of the most important components directly affecting yield in peanut. First and second quality pod ratios, with averages of 66.76% and 24.60% respectively, are important parameters in peanut quality classification.

In terms of physiological characteristics, leaf area index and chlorophyll values were measured during the 50% flowering and pod formation periods of peanut, with total chlorophyll amount in the pod formation period (41.13) showing an increase compared to the flowering period (38.91), reflecting the change in photosynthetic activity of peanut according to developmental stages. Awal and Ikeda (2002) reported that chlorophyll content in peanut varies according to developmental stages and this variation is related to photosynthetic activity. Chlorophyll b values show high variation in both flowering (23.68%) and pod formation periods (19.78%). Oil content in peanut seeds varies between 46.64-57.28%, with an average of 50.82%, showing that peanut is an important oilseed crop, and the low coefficient of variation (6.85%) indicates that this characteristic is relatively stable. These data can be used in peanut breeding programs to improve yield, quality, and physiological characteristics. Characteristics showing high variation, such as 100-seed weight, 100-pod weight, and chlorophyll content, can be evaluated in selection studies.

The peanut cultivars used in the study show significant variations in terms of agronomic, morphological, physiological, and quality characteristics. The ANOVA results in Table 5 show that there are statistically significant differences among cultivars in all parameters except second quality pod ratio and chlorophyll a content during the pod period ($p<0.01$ or $p<0.05$). Looking at Table 5, the 'Florispan' cultivar has the highest yield with 485.24 kg per decare and is statistically superior to all other cultivars. This is followed by 'Halisbey' (476.91 kg da^{-1}) and 'Osmaniye 2005' (447.4 kg da^{-1}). The lowest yield was observed in the 'Masal' cultivar (341.2 kg da^{-1}). Boydak (2020) found that the yield of peanut plants is affected by environmental factors and determined average yield values between 352.01-553.45 kg da^{-1}. These values are in line with our values.

In terms of 100-pod weight, the 'Rigel' cultivar (249.33 g) has the highest value, while 'Florispan' (105.33 g) shows the lowest value. Kadiroğlu (2012) reported that among different peanut cultivars (Georgia Green, NC-7, Florispan, and Halisbey), the highest 100-pod weight (334.60 g) was obtained from the Halisbey cultivar, while Koldanca (2016) reported that among different peanut cultivars (Halisbey, NC-7, and Batem-5025), the highest 100-pod weight was again obtained from the 'Halisbey' cultivar (64.3 g). The findings obtained partially overlap with the results of the researchers. Pod weight is a parameter affected by factors such as cultivar, climate, soil properties, and cultural practice differences (Karabulut and Tunçtürk, 2019).

For hundred-seed weight, 'NC-7' (112.93 g) and 'Masal' (111.93 g) cultivars stand out. The Florispan cultivar, which has the highest yield, has the lowest 100-seed weight (47.78 g). Aşık et al. (2018) determined 100-seed weight between 53.27-132.68 g in their study. Arıoğlu et al. (2016) obtained the highest 100-seed weight from the 'Osmaniye-2005' cultivar with 137.78 g. Different from these results, Eskalen and Yılmaz (1993) determined 100-

seed weight values between 70.89 g and 90.69 g in their research with NC-7, Çom, Gazipaşa, Shulamith, and NC-17 cultivars.

Table 4. Descriptive Statistics Values of the Investigated Characteristics of Peanut Genotypes

Variable	Abbreviation	Unit	Min	Max	Mean	StDev	CV%
Yield	Yield	kg da^{-1}	341.20	485.24	407.56	49.50	12.15
One hundred pod weight	OHuPoWe	g	105.33	249.33	197.50	45.05	22.81
One hundred seed weight	OHuSeWe	g	47.78	112.93	88.94	23.11	25.98
Shelling ratio	SeRa	%	52.56	71.87	62.15	5.98	9.62
Number of pods per plant	NuPoPePl	quantity	17.74	34.72	26.58	4.97	18.69
First quality pod rate	FiQuPoRa	%	61.43	74.40	66.76	3.37	5.04
Second quality pod rate	SeQuPoRa	%	19.35	28.71	24.60	2.60	10.57
Leaf area index during flowering period	LeArInDuFlPe	LAI	12.60	20.70	16.46	1.99	12.12
Total chlorophyll amount during flowering period	TaChAmDuFlPe	FCI (Falker Chlorophyll Index)	31.70	43.65	38.91	4.54	11.66
Chlorophyll a during flowering	ChADuFl	FCI (Falker Chlorophyll Index)	23.78	29.33	26.84	2.03	7.57
Chlorophyll b during flowering	ChBDuFl	FCI (Falker Chlorophyll Index)	7.33	14.11	11.18	2.65	23.68
Leaf area index during pod period	LeArInDuPoPe	LAI	11.41	16.91	14.03	2.07	14.78
Total chlorophyll in pod stage	ToChPoSt	FCI (Falker Chlorophyll Index)	34.43	45.43	41.13	3.67	8.93
Chlorophyll a in pod period	ChAPoPe	FCI (Falker Chlorophyll Index)	24.67	29.33	27.80	1.46	5.25
Chlorophyll b in pod period	ChBPoPe	FCI (Falker Chlorophyll Index)	7.33	15.33	12.47	2.47	19.78
Oil content	OC	%	46.64	57.28	50.82	3.48	6.85

In terms of shelling ratio, the 'Georgia Green' cultivar has the highest value with 71.87%. Çil et al. (2016) determined the average shelling ratios of genotypes in the range of 57.9-70.1%. For number of pods per plant, 'Georgia Green' (34.72) and 'Osmaniye-2005' (34.03) cultivars stand out, while the 'Halisbey cultivar' (17.74) shows the lowest value. Yaşlı et al. (2020) found that the number of pods per plant was between 32.95-48.68. İnan (2016) reported that the number of pods per plant was 17.23-39.92 in his study. In terms of first quality pod ratio, the 'Georgia Green' cultivar (74.40%) showed superior performance compared to other cultivars. Branch and Culbreath (2008) stated in their study that the 'Georgia Green' cultivar is known for its high-quality pod production characteristic.

For leaf area index during the flowering period, the 'Florispan' cultivar (20.70) is statistically superior to other cultivars. This situation can be explained by the fact that Florispan's high yield may be related to a larger leaf area and thus a higher photosynthetic capacity. Looking at the results in Table 6, in terms of total chlorophyll amount during the flowering period, 'Rigel' (43.65), 'Halisbey' (43.23), and 'Osmaniye-2005' (42.98) cultivars have the highest values. In terms of chlorophyll a content, the 'Gazipaşa' cultivar (29.33) stands out, while for chlorophyll b content, 'Halisbey' (14.11), 'Masal' (13.55), 'Osmaniye-2005' (13.89), and 'Rigel' (13.89) cultivars showed superior performance. These findings are consistent with Awal and Ikeda (2002)'s study reporting that chlorophyll content in peanut is related to photosynthetic capacity and yield potential.

In terms of leaf area index during the pod formation period, the Çom cultivar (16.91) has the highest value, followed by Rigel (16.42). 'Osmaniye-2005', 'Georgia Green', and 'Sultan' cultivars showed the lowest values. Arunyanark et al. (2008) reported that leaf area index during the pod formation period is critically important for assimilate production and pod filling. In terms of total chlorophyll amount during the pod period, 'Sultan' (45.43), 'Halisbey' (44.60), and 'Rigel' (44.10) cultivars stand out. For chlorophyll b content during the pod period, 'Sultan' (15.33), 'Halisbey' (14.67), and 'NC-7' (14.33) cultivars showed superior performance.

Table 5. Mean Values and Groupings of Yield and Morphological Characteristics of Different Peanut Varieties.

Variety	Yield	OHuPoWe	OHuSeWe	SeRa	NuPoPePl	FiQuPoRa	SeQuPoRa	LeArInDuFlPe
Çom	384,67±13,35 d	180,33±4,51 c	74,81±9,65 c	64,74±1,82 b	25,78±3,31 b	67,17±3,38 bc	25,15±2,58 a	16,22±1,34 b
Florispan	485,24±3,23 a	105,33±4,16 d	47,78±0,75 d	64,26±0,69 bc	24,75±2,28 bc	66,63±1,30 bc	26,04±3,45 a	20,70±0,76 a
Gazipaşa	366,16±22,04 de	201,33±9,45 bc	76,99±4,36 c	64,41±4,54 bc	25,94±2,41 b	69,53±0,70 ab	22,30±3,72 a	17,21±1,71 b
Georgia Green	382,92±10,09 d	135,33±5,77 d	58,54±3,95 d	71,87±1,94 a	34,72±1,66 a	74,40±2,15 a	19,35±6,65 a	16,46±0,93 b
Halisbey	476,91±13,4 ab	226,33±9,07 ab	109,21±4,71 ab	59,12±1,03 cd	17,74±2,27 c	66,13±2,33 bc	22,69±2,49 a	15,51±0,34 b
Masal	341,2±13,45 e	214,67±4,16 b	111,93±6,68 a	67,26±1,10 ab	22,49±2,66 bc	66,24±1,66 bc	25,88±1,25 a	16,50±0,35 b
NC-7	433,85±9,27 c	218,00±22 b	112,93±8,37 a	65,16±1,74 b	26,17±0,64 b	65,91±3,44 bc	24,18±3,64 a	12,60±0,14 c
Osmaniye 2005	447,4±8,05 bc	230,67±6,43 ab	99,68±1,44 ab	52,56±0,42 e	34,03±3,94a	61,43±1,00 c	28,71±2,16 a	17,22±1,16 b
Rigel	381,04±9,89 d	249,33±22,30 a	102,11±4,95 ab	56,18±1,03 de	27,65±2,10 ab	65,30±3,06 bc	25,74±2,94 a	16,62±1,18 b
Sultan	376,27±3,93 d	213,67±7,23 bc	95,44±4,53 b	55,90±0,68 de	26,56±2,76 b	64,83±2,57 bc	26,01±2,96 a	15,56±0,28 b
Anova								
F Ratio	52,49**	45,60**	51,31**	30,46**	11,41**	6,14**	1,69	12,91**

*OHuPoWe: One hundred pod weight, OHuSeWe: One hundred seed weight, SeRa: Shelling ratio, NuPoPePl: Number of pods per plant, FiQuPoRa: First quality pod rate, SeQuPoRa: Second quality pod rate, LeArInDuFlPe: Leaf area index during flowering period
** Significant P < 0.01, * significant P < 0.05

Table 6. Mean Values and Groupings of Physiological Characteristics and Oil Content of Peanut Varieties

Variety	TaChAmDuFlPe	ChADuFl	ChBDuFl	LeArInDuPoPe	ToChPoSt	ChAPoPe	ChBPoPe	OC
Çom	32,83±0,62 c	24,11±0,51 cd	8,00±0,33 bc	16,91±0,17 a	39,60±0,10 ab	28,67±1,15 a	10,33±1,15 ab	46,64±2,58 d
Florispan	35,09±1,23 bc	24,44±0,51 b-d	9,22±0,51 bc	15,74±0,89 a-c	37,83±2,80 ab	26,67±1,53 a	10,67±1,53 ab	51,54±1,57 b-d
Gazipaşa	41,65±3,24 ab	29,33±2,51 a	11,33±4,58 ab	14,26±0,38 cd	34,43±2,39 b	26,33±2,52 a	7,33±1,53 b	47,43±1,05 d
Georgia Green	39,19±3,06 a-c	26,78±1,02 a-d	11,55±2,04 ab	11,41±1,24 e	42,47±1,01 ab	28,33±1,15 a	13,33±0,58 ab	50,90±2,20 b-d
Halisbey	43,23±3,46 a	28,22±1,50 a-d	14,11±1,83 a	15,22±0,12 bc	44,60±4,08 a	29,00±1,73 a	14,67±2,52 a	57,28±2,55 a
Masal	42,22±4,56 ab	27,78±1,50 a-d	13,553,02 a	14,33±0,04 cd	42,03±3,67 ab	28,00±1,73 a	13,00±2,64 ab	53,35±3,31 a-c
NC-7	31,7±0,61 c	23,78±0,39 d	7,33±0,33 c	12,69±0,23 de	43,57±3,40 a	28,33±1,53 a	14,33±2,52 a	47,10±1,17 d
Osmaniye 2005	42,98±2,15 a	28,33±0,88 a-c	13,89±1,35 a	11,51±0,39 e	37,20±0,78 ab	24,67±4,04 a	11,67±3,78 ab	48,95±1,30 cd
Rigel	43,65±3,64 a	28,67±1,66 ab	13,89±2,01 a	16,42±0,37 ab	44,10±2,79 a	28,67±0,58 a	14,00±2,00 ab	50,43±0,79 b-d
Sultan	36,55±0,20 a-c	27,00±2,90 a-d	8,89±2,27 bc	11,76±0,69 e	45,43±4,29 a	29,33±1,15 a	15,33±3,05 a	54,59±1,05 ab
Anova								
F Ratio	8,48**	5,05**	4,27**	38,72**	4,87**	1,69	3,40*	9,73**

*TaChAmDuFlPe: Total chlorophyll amount during flowering period, ChADuFl: Chlorophyll a during flowering, ChBDuFl: Chlorophyll b during flowering, LeArInDuPoPe: Leaf area index during pod period, ToChPoSt: Total chlorophyll in pod stage, ChAPoPe: Chlorophyll a in pod period, ChBPoPe: Chlorophyll b in pod period, OC: Oil content
** Significant P < 0.01, * significant P < 0.05

Significant differences in oil content were observed among cultivars. The 'Halisbey' cultivar has the highest oil content with 57.28%, followed by 'Sultan' (54.59%) and 'Masal' (53.35%). The lowest oil content was detected in 'Çom' (46.64%), 'Gazipaşa' (47.43%), and 'NC-7' (47.10%) cultivars. The 'Florispan' cultivar, which has the highest yield, showed average values in physiological parameters. This supports the view of Prasad et al. (2010) that yield in peanut depends not on a single physiological parameter but on the complex interaction of many factors. The study conducted by Bakal et al. is in agreement with our findings (Bakal et al. 2022). On the other hand, the fact that the high-yielding Halisbey cultivar has high chlorophyll content in both flowering and pod periods and high oil content shows the potential effect of these physiological characteristics on yield and quality.

The correlation analysis in Figure 2 shows the relationships between agronomic and physiological characteristics of peanut cultivars. According to the correlation analysis results, a negative correlation (-0.31) was observed between yield and first quality pod ratio. This supports the finding of Canavar and Kaynak (2013) that quality parameters can sometimes be adversely affected in high-yielding peanut cultivars. There is a positive correlation (0.21) between yield and leaf area index during the flowering period.

Among morphological characteristics, there is a very strong positive correlation (0.91) between 100-pod weight and 100-seed weight. Strong negative correlations were observed between shelling ratio and 100-pod weight and 100-seed weight (-0.62 and -0.43, respectively). This supports the finding of Arıoğlu et al. (2018) that shell thickness may increase and shelling ratio may decrease in large-podded cultivars. There is a very strong positive correlation (0.83) between first quality pod ratio and shelling ratio. Kurt et al. (2017) reported that quality pods generally have a higher shelling ratio. There is a very strong negative correlation (-0.91) between first and second quality pod ratios, which is an expected result.

Very strong positive correlations were observed between total chlorophyll amount during the flowering period and chlorophyll a and chlorophyll b (0.94 and 0.97, respectively). Arunyanark et al. (2008) reported that total chlorophyll amount is directly related to chlorophyll a and b contents and these parameters reflect photosynthetic activity. Similar strong positive correlations (0.83 and 0.95, respectively) were found between total chlorophyll amount during the pod period and chlorophyll a and chlorophyll b. There is a positive correlation (0.30) between leaf area index during the flowering period and leaf area index during the pod period. A strong positive correlation (0.59) was observed between oil content and chlorophyll b content during the pod period. There is a negative correlation (-0.48) between oil content and number of pods per plant. This supports the view of Prasad et al. (2010)

that as the number of pods increases in peanut, the amount of assimilate transferred to each pod may decrease, which may adversely affect oil content.

The heat map and cluster analysis show the hierarchical clustering of peanut cultivars (1-10) and the characteristics examined (Figure 3). Cultivars are divided into two main groups (X and Y). Cluster X consists of subclusters X1 (1, 7, 2) and X2 (3, 4). Cultivars in this cluster generally show similarity in terms of yield and morphological characteristics. Cluster Y consists of subclusters Y1 (5, 6, 9, 10) and Y2 (8). Cultivars in this cluster show similarity in terms of physiological characteristics and oil content.

Characteristics are also divided into two main groups (A and B): Cluster A consists of subclusters A1 (Yield, SeQuPoRa, LeArInDuFlPe) and A2 (LeArInDuPoPe, SeRa, FiQuPoRa, NuPoPePl). This cluster generally includes yield and morphological characteristics. Cluster B consists of subclusters B1 (OHuSeWe, OHuPoWe, TaChAmDuFlPe, ChADuFl, ChBDuFl) and B2 (ToChPoSt, ChBPoPe, ChAPoPe, OC). This cluster covers physiological characteristics and oil content.

Cluster analysis is a method used to group genotypes according to the characteristics examined and determine the relationship between them. Sanches et al. (2006), in their study, examined morphological characteristics such as number of pods, seed weight, pod length, and plant height among 64 peanut cultivars and stated that the relationship between these characteristics stems from genotypes. This also supports the finding of Arunyanark et al. (2008) that physiological characteristics in peanut are related to each other and to quality parameters. Additionally, Holbrook and Stalker (2003) emphasized that agronomic and physiological characteristics in peanut generally cluster in different groups and this situation should be taken into account in breeding studies.

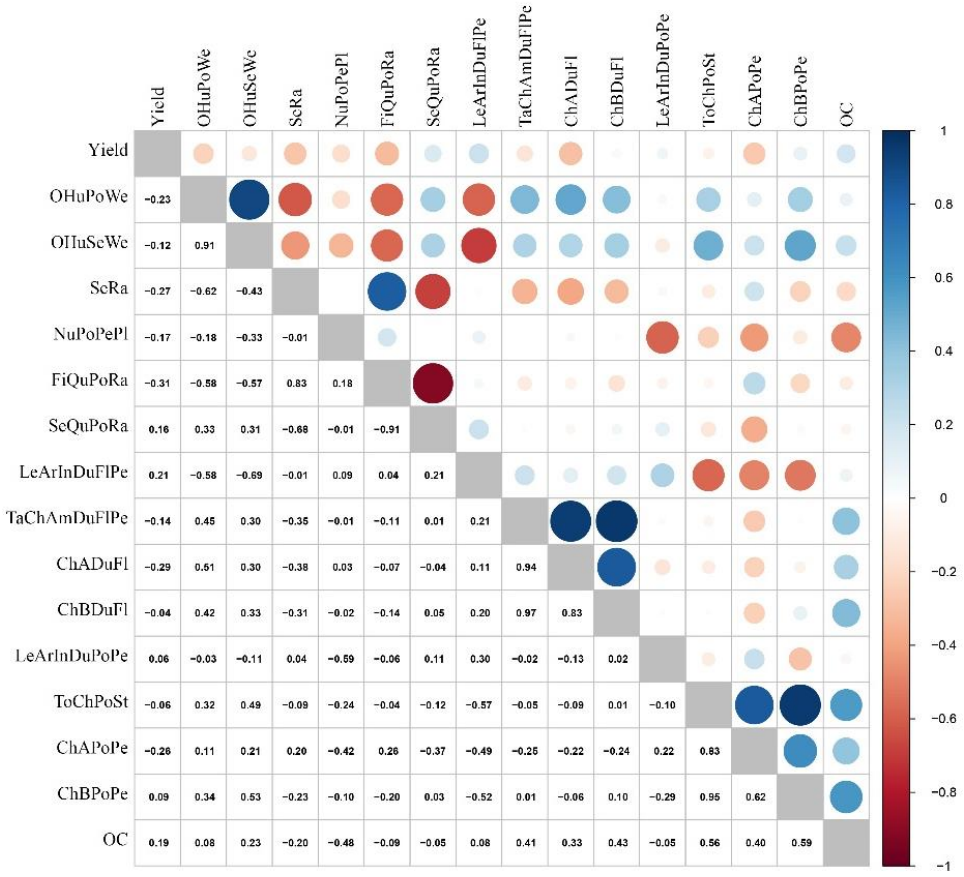

Figure 2. Correlation Analysis of Peanut Varieties.

*OHuPoWe: One hundred pod weight, OHuSeWe: One hundred seed weight, SeRa: Shelling ratio, NuPoPePl: Number of pods per plant, FiQuPoRa: First quality pod rate, SeQuPoRa: Second quality pod rate, LeArInDuFlPe: Leaf area index during flowering period, TaChAmDuFlPe: Total chlorophyll amount during flowering period, ChADuFl: Chlorophyll a during flowering, ChBDuFl: Chlorophyll b during flowering, LeArInDuPoPe: Leaf area index during pod period, ToChPoSt: Total chlorophyll in pod stage, ChAPoPe: Chlorophyll a in pod period, ChBPoPe: Chlorophyll b in pod period, OC: Oil content

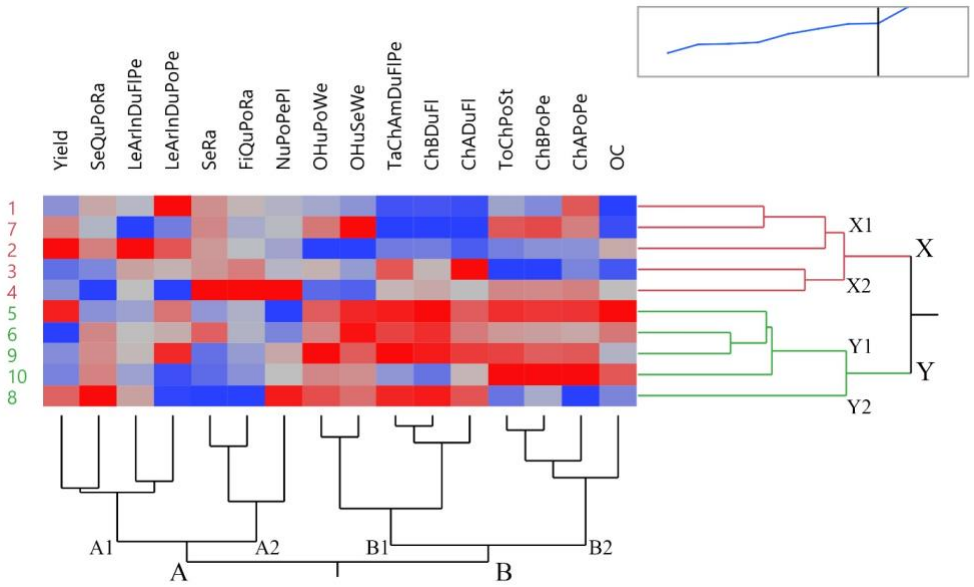

Figure 3. Heat map obtained as an output of the hierarchical cluster analysis of varieties and traits studied. Colors shifting to red indicate an increase and colors shifting to blue indicate a decrease in the temperature scale.
*OHuPoWe: One hundred pod weight, OHuSeWe: One hundred seed weight, SeRa: Shelling ratio, NuPoPePl: Number of pods per plant, FiQuPoRa: First quality pod rate, SeQuPoRa: Second quality pod rate, LeArInDuFlPe: Leaf area index during flowering period, TaChAmDuFlPe: Total chlorophyll amount during flowering period, ChADuFl: Chlorophyll a during flowering, ChBDuFl: Chlorophyll b during flowering, LeArInDuPoPe: Leaf area index during pod period, ToChPoSt: Total chlorophyll in pod stage, ChAPoPe: Chlorophyll a in pod period, ChBPoPe: Chlorophyll b in pod period, OC: Oil content

CONCLUSION

In this study, agronomic, morphological, and physiological characteristics of different peanut genotypes were comprehensively examined. The research results revealed significant variations among peanut cultivars in terms of yield and quality parameters. Yield per decare varied between 341.20-485.24 kg, with the 'Florispan' cultivar achieving the highest yield. In terms of morphological characteristics, the 'Rigel' cultivar (249.33 g) stood out in 100-pod weight, 'NC-7' (112.93 g) in 100-seed weight, and the 'Georgia Green' cultivar (71.87%) in shelling ratio. 'Georgia Green' and 'Osmaniye-2005' cultivars showed superior performance in number of pods per plant, while the 'Georgia Green' cultivar excelled in first quality pod ratio. When physiological parameters were examined, Florispan in leaf area index during the flowering period, and 'Rigel', 'Halisbey', and 'Osmaniye-2005' cultivars reached high values in total chlorophyll amount. During the pod formation period, the 'Çom' cultivar had the highest leaf area index, while 'Sultan', 'Halisbey', and 'Rigel' cultivars stood out in total chlorophyll amount. In terms of oil content, the 'Halisbey' cultivar (57.28%) reached the highest value compared to other cultivars.

According to the correlation analysis, strong positive relationships were determined between 100-pod weight and 100-seed weight (0.91), negative relationship between shelling ratio and pod weight (-0.62), and positive relationship between oil content and chlorophyll b content during the pod period (0.59).

Cluster analysis divided peanut cultivars into two main groups: Cluster X (Çom, NC-7, Florispan, Gazipaşa, Georgia Green) showed similarity in yield and morphological characteristics, while Cluster Y (Halisbey, Masal, Rigel, Sultan, Osmaniye-2005) showed similarity in physiological characteristics and oil content. The examined characteristics were also grouped into two clusters: agronomic-morphological (Cluster A) and physiological-quality (Cluster B) parameters. This grouping facilitates cultivar selection according to target characteristics in breeding studies.

These findings provide valuable information for developing yield, quality, and physiological characteristics in peanut breeding programs.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Declaration of Interests

The authors have no conflict of interest to declare.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the text, figures, and tables are original and that they have not been published before.

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