How to cite: Güngör, O. & İ. Akıncı, 2025. Investigation of selected physico-mechanical properties of the Office 2 (white) poppy plant. Ege Univ. Ziraat Fak. Derg., 62 (3): 381-390, https://doi.org/10.20289/zfdergi.1660014

Research Article
(Araştırma Makalesi)

Ege Üniv. Ziraat Fak. Derg., 2025, 62 (3):381-390
https://doi.org/10.20289/zfdergi.1660014

Investigation of selected physico-mechanical properties of the Office 2 (white) poppy plant*

Ofis 2 (beyaz) haşhaş bitkisinin seçilmiş fiziko-mekanik özelliklerinin incelenmesi

Orhan GÜNGÖR [1*]

İbrahim AKINCI [2]

[1] Burdur Mehmet Akif Ersoy University, Gölhisar Vocational School, Department of Computer Technologies, 15600, Gölhisar, Burdur, Türkiye.

[2] Akdeniz University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, 07100, Kepez, Antalya, Türkiye.

* Corresponding author(Sorumlu yazar):
orhangungor@mehmetakif.edu.tr

* This article first author It has been summarized from the author's doctoral dissertation.

Received (Alınış): **17.03.2025** **Accepted** (Kabul Tarihi):**28.05.2025**

ABSTRACT

Objective: This study aims to selected physico-mechanical properties of the Office 2 (white) poppy plant , which is widely produced in Türkiye.

Material and Methods: Dimensional and mass measurements of poppy capsule were made with digital devices and moisture content was determined by oven drying method. Critical velocity was determined by the aspiration method, while shearing forces of the stem and breaking forces of the capsule were measured by the mechanical test device.

Results: The average height of the capsule was 37.58 mm; the width was 37.52 mm; the mass was 6.14 g; the volume was 360.06 mm³; the critical velocity was 9.87 m/s; and the shell ratio was 43.93%. The shear force of the stem was 35 -129 N and the capsule breaking force was 199.32 N vertically and 132.68 N horizontally.

Conclusion: The findings provide a scientific basis for the development of mechanised harvesting processes for poppy crops.

Keywords: Biological material, cutting-compression tests, Office 2 (white) poppy, physico-mechanical properties

ÖZ

Amaç: Bu çalışmada Türkiye'de yaygın olarak yetiştirilen Ofis 2 (beyaz) haşhaş bitkisinin seçilmiş fiziko-mekanik özellikleri araştırılmıştır.

Materyal ve Yöntem: Haşhaş kapsülünün boyutsal ve kütlesel ölçümleri dijital cihazlarla yapılmış, nem içeriği fırında kurutma yöntemiyle belirlenmiştir. Kritik hız hava kanalı kullanımıyla tespit edilirken, sapın kesme ve kapsülün kırılma kuvvetleri mekanik test cihazı ile ölçülmüştür.

Araştırma Bulguları: Kapsülün ortalama yüksekliği 37.58 mm, çapı 37.52 mm, kütlesi 6.14 g, hacmi 360.06 mm³, kritik hızı 9.87 m/s ve kabuk oranı %43.93 olarak belirlenmiştir. Sapın kesme kuvveti 35 - 129 N, kapsül kırılma kuvveti ise dikeyde 199.32 N, yatayda 132.68 N olarak tespit edilmiştir.

Sonuç: Elde edilen veriler hasat ve hasat sonrası süreçte yararlanılabilecek bazı fiziksel özellikleri ortaya koymaktadır.

Anahtar sözcükler: Biyolojik malzeme, kesme-basma testleri, Ofis 2 (beyaz) haşhaş, fiziko-mekanik özellikler

INTRODUCTION

The cultivation of the poppy plant, particularly "*Papaver somniferum*" (opium poppy), is important due to its diverse applications in both the pharmaceutical and food industries. The opium poppy is known for producing benzylisoquinoline alkaloids, including morphine, codeine, and thebaine, which are essential for medical purposes (Bulut et al., 2020; Hong et al., 2021). Successful cultivation requires careful consideration of sowing dates and densities, as these factors significantly influence crop yield. Research has demonstrated that optimal sowing times enhance capsule density and seed yield. For example, early sowing has been shown to increase overall yield, resulting in more capsules per plant and larger capsule sizes (Zając et al., 2012; Neugschwandtner et al., 2023).

Genetic differences among poppy varieties play a key role in determining alkaloid profiles and productivity. While some varieties are bred for high alkaloid content, others are optimized for food applications requiring negligible alkaloid levels (Aleem et al., 2021; Hong et al., 2021). Studies also indicate that shading during later stages of capsule development can enhance alkaloid yield by manipulating environmental conditions (Hope et al., 2020). White-seeded varieties generally exhibit lower morphine content compared to blue-seeded varieties, which are often selected for higher alkaloid production (Skalický et al., 2014).

In Türkiye, following the establishment of the Republic, the cultivation of poppy plants commenced in 1933. Nevertheless, between 1971 and 1974, poppy production was prohibited. Since 1987, its cultivation has been subject to regulation and oversight by the Turkish Grain Board (TMO) (Hacıyusufoğlu, 2013). Globally, poppy cultivation covers an area of 87,642 hectares, with Türkiye accounting for 64% (56,511 hectares) of this total, making it the leading producer worldwide (TMO, 2019). In Türkiye, the primary poppy varieties include Office 2 (white), Office 1 (blue), and Office 4 (yellow), with white-seeded varieties being the most prevalent (69%), followed by blue (17%) and yellow (14%) varieties (Güngör, 2023). Poppy seeds may vary in color, ranging from blue and yellow to pink, white, and brown. According to 2022 statistics, poppy capsule production in Türkiye reached 12,240 tons (Baka, 2022).

Figure 1 illustrates the development process and vegetative components of the white poppy plant. This developmental process encompasses the stages of leaf emergence, bud initiation, flowering, capsule development, and eventual maturation (Güngör & Akıncı, 2024). The vegetation period typically lasts 110 to 280 days, and agricultural practices, such as sowing time and soil management, significantly impact poppy yield and alkaloid content. Studies indicate that both autumn and spring sowing affect the morphine and oil content of Turkish poppy varieties, emphasizing the importance of optimizing sowing conditions for maximum productivity (Gümüşçü & Gümüşçü, 2015; Kara, 2017). Furthermore, environmental factors, including climate change, can alter growth conditions, potentially affecting yield and alkaloid concentrations (Widener et al., 2012; Gümüşçü & Gümüşçü, 2015). After sowing, agricultural practices including thinning, irrigation, fertilization, pest management, and harvesting are carried out (İşler, 2024). The vegetative parts of the poppy plant include a primary stem, leaves, lateral branches, and capsules, each developing at a node on the main stem (Güngör, 2023).

Harvesting occurs when crops reach physiological maturity. In the case of medicinal and aromatic plants, the ideal harvest period corresponds to a moisture content level between 7% and 12%, ensuring optimal quality and preservation of active compounds (Baydar, 2009). Poppy plants are harvested manually by breaking capsules at the node. Mechanized harvesting, however, requires cutting stalks 10–20 cm below the node (Hacıyusufoğlu, 2013). Understanding the physico-mechanical properties, such as dimensions, mass, volume, critical velocity, and natural repose angle, is crucial for designing efficient harvesting machinery (Dash et al., 2008; Polyák & Csizmazia, 2016).

Given these considerations, this study aims to determine the key physico-mechanical properties of the Office 2 (white) poppy plant, with a focus on optimizing harvesting machinery design and improving processing efficiency.

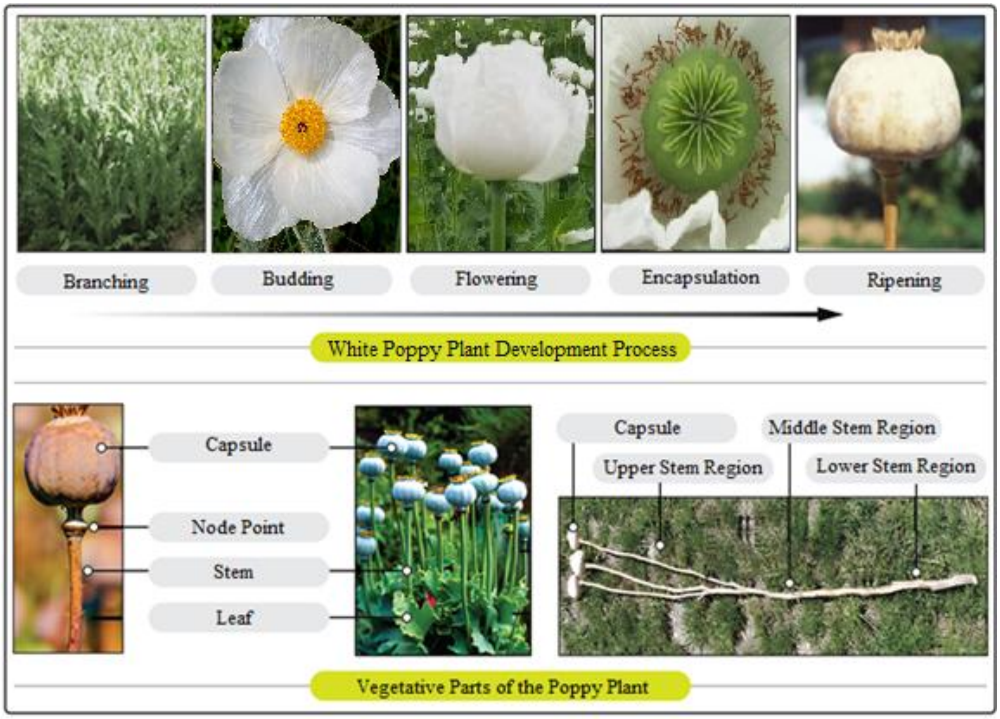

Figure 1. Development process and vegetative parts of white poppy plant.

Şekil 1. *Beyaz haşhaş bitkisinin gelişim süreci ve vejetatif kısımları.*

MATERIALS and METHODS

Data were analyzed using Microsoft Excel. Excel's built-in statistical functions were used to calculate the mean and standard deviation. Standard deviation represents how much the individual values in a dataset deviate from the arithmetic mean. It is commonly used in biological and agricultural measurements to describe data variability. No comparisons were made between groups; only descriptive statistics (mean, SD) were reported to represent variation. In the study, samples were taken using the randomized plot method. Each treatment was applied in 1 m² plots and five replicates were applied for each treatment. The randomized plot method is widely used in agricultural experiments in such small plots (Gomez & Gomez, 1984).The plant material used in the trials was the Office 2 (white) poppy variety, developed in 2016 by the Turkish Grain Board (Toprak Mahsulleri Ofisi – TMO). All dimensional analyses and mechanical tests carried out in this study were conducted in accordance with the measurement protocols outlined in Kara's publication, "Physical Properties of Biological Products".

Dimensional measurements of the poppy capsules were performed using a digital caliper with an accuracy of 0.1 mm. The mass of each capsule was determined using a precision digital scale with a sensitivity of 0.01 g. The shell ratio was calculated by dividing the mass of the capsule shell by the total mass of the capsule. Capsule volume was determined via the liquid displacement method, in which each capsule was immersed in a graduated container filled with toluene, and the volume of displaced liquid was recorded (Kara, 2012). The vertical and horizontal projection areas of the capsules were determined by image analysis. The capsules were placed on a 10 cm^2 plate and digital distances were taken from a fixed height. The projection area values were calculated by proportioning the area of the plate with the image analysis program. To determine the critical velocity, the aspiration method was applied as described by Kara (2012); critical velocity was defined as the airflow speed at which the capsules became suspended in the airstream. A cylindrical container with two open ends, 30 cm in diameter and 50 cm in height, is placed on a plate. The cylinder in which the capsules are placed is lifted upwards. The ratio of the height of the resulting cone to its radius gives the angle of accumulation (Kara, 2012). Measurements for assessing the physico-mechanical properties of the poppy capsule were conducted with multiple repetitions to ensure precision.

The moisture content of poppy capsules and stems was determined using the oven drying method by measurements on five samples. The poppy capsules and stems were dried in a drying oven at 105° for 24 hours. The moisture content was expressed as percentage on wet basis (Mohsenin, 1986). During stalk cutting and capsule compression/crushing trials, harvest moisture values ranging from 7% to 12% were considered (Baydar, 2009).

The "Unit Area Method" was employed to determine the number of plants per unit area, plant heights, and the number of capsules both overall and per plant. A 1 m² plot was designated as the unit area, and random sampling was conducted in the poppy field. Each trial was repeated five times. In each unit area, plant and capsule counts were determined, plant heights were measured, and the number of capsules per plant was recorded. To assess the cutting force values for poppy stems, measurements were taken at three distinct regions: lower, middle, and upper sections. The average diameters of these sections were 8.8 mm, 4.3 mm and 3.1 mm, respectively. Shear tests were conducted at these sites. Cutting trials were conducted in these regions. In order to evaluate the compressive strength of poppy capsules, both vertical and horizontal compression tests were conducted. These experiments were carried out on the TST Mares universal mechanical testing machine located in the Akdeniz University Faculty of Agriculture Laboratory. Each test was replicated five times to ensure reliability of the results. Representative images illustrating the dimensional measurements and mechanical testing procedures are provided in Figure 2. The compression rate is 5 mm/min.

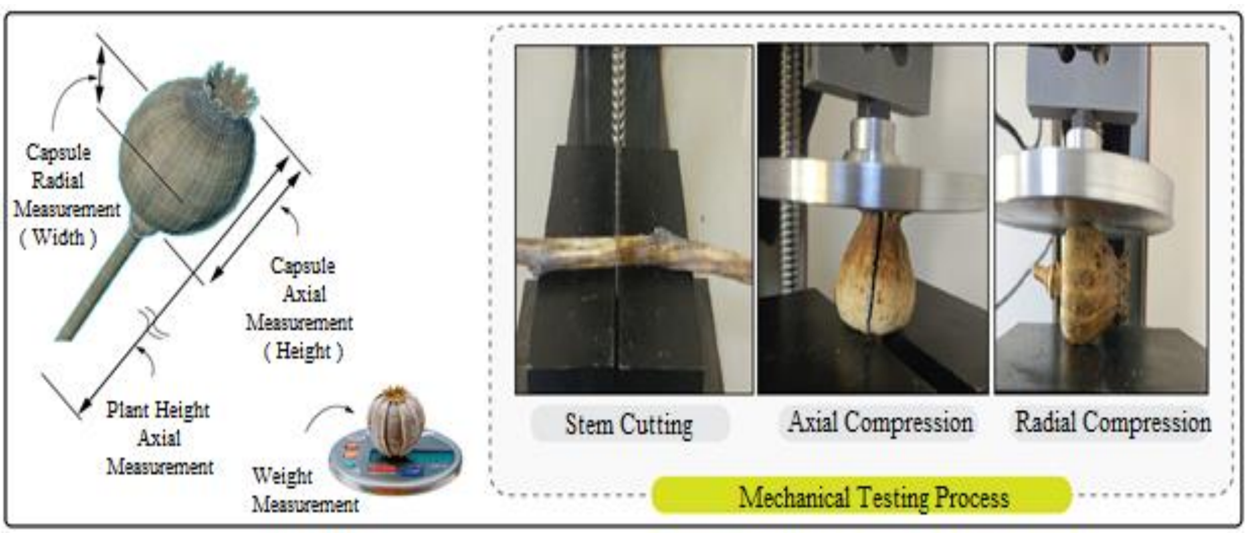

Figure 2. Visual documentation of sample dimensional measurements and mechanical tests .

Şekil 2. *Örnek boyut ölçümlerinin ve mekanik testlerin görsel dokümantasyonu.*

RESEARCH FINDINGS

In this study, physico-mechanical properties of the Office 2 (White) poppy capsule were determined, with parameters intended for use in the design of harvesting machinery units, including separation, cutting, collection, threshing, cleaning, transfer, and storage. Some of these physico-mechanical properties are summarized in Table 1.

Table 1. Some physico-mechanical properties of white poppy capsule

Çizelge 1. *Beyaz haşhaş kapsülüne ait bazı fiziko-mekanik özellikler*

The characteristic of the material	Average Value ± SD
Height (mm)	37.58 ±2.94
Width (mm)	37.52 ±5.53
Mass (g)	6.14 ±1.94
Volume (mm^3)	360.06 ±23.26
Horizontal Projection Area (cm^2)	17.28 ±2.77
Vertical Projection Area (cm^2)	18.09 ±3.49
Critical Velocity ($m\ s^{-1}$)	9.87 ±1.39
Natural Angle of Repose (degrees)	21.90 ±0.81
Shell Ratio (%)	43.93 ±0.91

According to Table 1, the height of the white poppy capsule is comparable to its width. A similar closeness is observed in the projection area values, indicating that the capsules have an oval shape. Capsule mass, volume, critical velocity, and natural angle of repose were determined as 6.14 g, 360.06 mm^3, 9.87 $m\ s^{-1}$, and 21.90°, respectively. The shell ratio was found to be 43.93%, indicating that the seed content within the capsule (56.07%) is higher than the shell content.

Moisture content values for different parts of the plant play a critical role in determining the timing of harvest and in the design of cutting, threshing, and cleaning units for harvesting machinery. Moisture content values for the white poppy stem and capsule are presented in Table 2.

Table 2. Moisture content values of white poppy stem and capsule

Çizelge 2. *Beyaz haşhaş sapı ve kapsülüne ait nem içeriği değerleri*

Plant component	The characteristic of the material	Average Value ± SD
Stem	Moisture Content of the Upper Stem Region w.b.(%)	12.40 ±3.36
	Moisture Content of the Middle Stem Region w.b. (%)	10.40 ±1.04
	Moisture Content Of The Lower Stem Region w.b.(%)	9.42 ±1.38
	Average (%)	10.74 ±1.24
Capsule	Moisture Content of the Seed Capsule Shell w.b.(%)	6.22 ±0.45
	Moisture Content of the Empty Capsule Shell w.b.(%)	8.05 ±0.66
	Average (%)	7.14 ±0.92

As seen in Table 2, the average moisture content of poppy stem and capsule was determined as 10.74% and 7.14%, respectively. No significant difference was observed in the moisture content between the upper, middle and lower regions of the plant stem. This shows that the moisture is distributed homogeneously within the stem and allows cutting to take place at different heights during mechanical harvesting. The low variation in moisture content in different stem regions increases the cutting efficiency and improves the overall efficiency of the harvesting process.

The similarity in moisture content between the seeded and empty capsule shells suggests that threshing, seed-shell separation, and seed cleaning processes can be effectively carried out. This homogeneity in capsule moisture content increases efficiency during post-harvest processing and minimizes potential quality losses. This, thus aiding the development of strategies to enhance poppy production.

The values presented for the parameters in Tables 3,4,5 represent the mean ± standard deviation calculated from five replicates. No statistical tests were performed to compare differences between groups.Data related to plant density, capsule number, and capsule/plant ratio in the unit area, of the white poppy plant are summarized in Table 3.

Table 3. Plant density per unit area, number of capsules, and the capsule-to-plant ratio

Çizelge 3. *Birim alandaki bitki yoğunluğu, kapsül sayısı ve kapsül-bitki oranı*

Replication	Plant count (piece m^{-2})	Capsule count (piece m^{-2})	Capsule/Plant ratio (Decimal)
1	25	42	1.7
2	23	38	1.7
3	24	41	1.7
4	21	38	1.8
5	27	43	1.6
Average (piece)	24.0	40.4	1.7
Standard Deviation	2.0	2.1	0.1

As indicated in Table 3, the number of plants per unit area varied between 21 and 27 plants/m² across replications. The number of capsules ranged from 38 to 43 capsules/m², while the capsule/plant ratio fluctuated between 1.6 and 1.8. The average values were calculated as 24.0 plants/m², 40.4 capsules/m², and an average capsule/plant ratio of 1.7. These findings demonstrate that each plant produces, on average, one capsule, and capsule distribution is relatively uniform across the plant population. The low variability in the capsule/plant ratio suggests that agricultural practices adhered to appropriate technical standards during the cultivation process.

In poppy cultivation, achieving uniform plant height and producing a single capsule per plant are desirable traits for product quality and harvesting efficiency. Table 4 presents plant density values according to plant height groups.

Table 4 illustrates that the plant density varied between 21 and 27 plants/m². The average plant density was calculated as 24 plants/m². The highest plant density was observed in the 106-125 cm height group, accounting for 44 plants/m² (36.67%), followed by the 86-105 cm group with 36 plants/m² (30.00%), the 126-145 cm group with 32 plants/m² (26.67%), the >146 cm group with 5 plants/m² (4.17%), and the <85 cm group with 3 plants/m² (2.50%). The average plant height was calculated as 115.34 cm.

Table 4. Plant density per unit area based on plant height groups

Çizelge 4. *Bitki boyu gruplarına göre birim alandaki bitki yoğunluğu*

Replication	Plant height classes					Overall plant count
	<85 cm	86-105 cm	106-125 cm	126-145 cm	146 cm>	(count m^{-2})
1	1	7	8	7	2	25
2	1	7	8	6	1	23
3	0	6	10	7	1	24
4	1	7	8	4	1	21
5	0	9	10	8	0	27
Average (count m^{-2})	0.6	7.2	8.8	6.4	1	24
Total (count m^{-2})	3	36	44	32	5	120
Ratio (%)	2.50	30.00	36.67	26.67	4.17	100

Considering the uniform moisture distribution in the plant stems (Table 2), it is advisable to set the cutting height below 85 cm during mechanical harvesting to reduce cutting losses. Additionally, breeding efforts aimed at achieving greater uniformity in plant height could enhance the efficiency of mechanization processes and significantly improve production efficiency.

Attaining a single capsule per plant is essential for both product quality and successful harvesting. Table 5 presents plant density values according to capsule number groups.

Table 5. Plant density per unit area based on capsule number groups

Çizelge 5. *Kapsül sayısı gruplarına göre birim alandaki bitki yoğunluğu*

Repetition	Capsule count groups				Total plant count
	1	2	3	4+	(count m^{-2})
1	15	5	3	2	25
2	16	2	2	3	23
3	14	5	3	2	24
4	12	4	2	3	21
5	19	3	2	3	27
Average (count m^{-2})	15.2	3.8	2.4	2.6	24
Total (count m^{-2})	76	19	12	13	120
Ratio (%)	63.33	15.83	10.00	10.83	100.00

As shown in Table 5, the total number of plants per unit area varied between 21 and 27. The average value was calculated as 24 plants/m². The highest plant density was observed in the single-capsule group, with 76 plants/m² (63.33%), followed by the two-capsule group (19 plants/m², 15.83%), the three-capsule group (12 plants/m², 10.00%), and the four-or-more capsule group (13 plants/m², 10.83%). These findings highlight the predominance of single-capsule plants, which is advantageous for mechanization processes. Furthermore, breeding programs aimed at cultivating exclusively single-capsule plants could enhance both product yield and mechanization efficiency.

Cutting force and capsule compression/crushing force values are critical for the design and optimization of cutting and threshing units in harvesting machinery. The cutting force values for the white poppy stem and the compression/crushing force values for the poppy capsule are summarized in Table 6.

Table 6. Shear force values of white poppy stem and capsule

Çizelge 6. *Beyaz haşhaş sapı ve kapsülüne ait kesme kuvveti değerleri*

Plant Component	Parameter	Average Value ± SD
Stem	Force required for cutting in the upper stem region (N)	35.00 ±10.99
	Force required for cutting in the middle stem region (N)	72.50 ±23.38
	Force required for cutting in the lower stem region (N)	129.00 ±17.54
	Average pressing force (N)	78.83 ±38.63
Capsule	Horizontal pressing force (N)	132.68 ±33.20
	Vertical pressing force (N)	199.32 ±25.52
	Average pressing force (N)	166,00 ±29.36

As indicated in Table 6, the cutting force values for the poppy stem were found to be 35.00 N, 72.50 N, and 129.00 N for the upper, middle, and lower sections, respectively. These values indicate that the cutting force increases toward the lower part of the plant stem. Figure 3 illustrates the force-deformation curve corresponding to the lower region of the poppy stem.

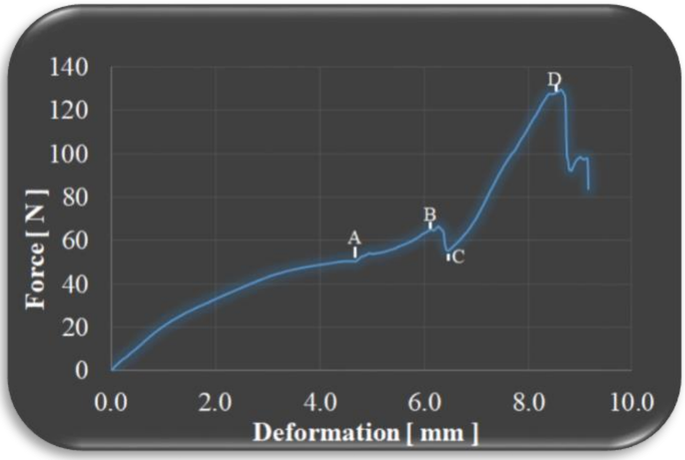

Figure 3. Force-deformation curve of poppy stem.

Şekil 3. *Haşhaş sapının kuvvet-deformasyon eğrisi*

a. The region up to point A represents the linear elastic region where Hooke's law is applicable.

b. The A–B region corresponds to continued elastic deformation of the material.

c. The B–C segment indicates the onset of plastic deformation.

d. The C–D region reflects further deformation under compression.

e. Point D marks the fracture point of the material.

This increase, attributed to structural differences within the stem, is a critical factor to consider in the design of cutting units for harvesting machinery. The variation in cutting force across different stem sections also plays a crucial role in determining optimal cutting heights. Consequently, cutting from the upper stem section during harvesting may reduce the required cutting force and enhance harvesting efficiency.

The vertical compression force for the capsule was determined as 199.32 N, while the horizontal compression force was 132.68 N (Table 6). The higher vertical compression force indicates that the capsules exhibit greater resistance in the vertical direction, which significantly impacts capsule crushing and seed-shell separation during post-harvest processing. These values can inform the optimization of threshing units and enhance mechanization efficiency by determining the most appropriate force settings for capsule crushing and seed separation processes.

CONCLUSION

This study examined various selected physico-mechanical properties of the Office 2 (White) poppy plant. According to the findings, the height, width, mass, and volume of the poppy capsule were determined as 37.58 mm, 37.52 mm, 6.14 g, and 360.06 mm³, respectively. The projected horizontal and vertical areas of the capsule were measured as 17.28 cm² and 18.09 cm². The capsule's critical velocity and natural angle of repose were found to be 9.87 m/s and 21.90°, respectively. The shell ratio was calculated as 43.93%.

The plant density in the poppy field indicated that the total number of plants per unit area varied between 21 and 27 plants/m², while the number of capsules ranged from 38 to 43 capsules/m². The average plant density and capsule density were calculated as 24 plants/m² and 40.4 capsules/m², respectively. The plant height distribution revealed that the highest plant density occurred in the 106-125 cm height group, representing 36.67% of the population, followed by the 86-105 cm and 126-145 cm groups.

The cutting forces measured for the upper, middle, and lower segments of the poppy stem were 35.00 N, 72.50 N, and 129.00 N, respectively. The capsule's compression forces were recorded as 132.68 N in the horizontal direction and 199.32 N in the vertical direction.

Poppy production is influenced by the complex interactions between genetic diversity, agricultural practices, and biotechnological advancements. Understanding these factors is essential to optimizing poppy cultivation to meet the demands of both the pharmaceutical and food industries.

In this study, only descriptive statistics were employed to characterize the physico-mechanical properties of the white poppy plant, and no inferential statistical tests were conducted between groups. Despite this limitation, the findings provide essential design parameters such as capsule dimensions, force requirements, and plant density that are critical for the development and optimization of mechanized harvesting systems. Future research should aim to incorporate inferential statistical analyses by including multiple factors and comparative evaluations across different poppy varieties and cultivation conditions to enhance the generalizability and applicability of the results.

Data Availability

Data will be made available upon reasonable request.

Author Contributions

Concept and design of the study: OG, İA; Sample collection: OG; Analysis and interpretation of data: İA; Statistical analysis:İA, OG; Visualization: OG; Article writing: OG, İA.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that an ethics committee is not required for this study.

Financial Support

This study was not financially supported.

Article Description

This article was edited by Section Editor Dr. İlkbal AYGÜN.

REFERENCES

Aleem, M., A. Akhtar, S. Aslam, R. Khan, Z. Ahmed & N. Khalid, 2021. Review on physicochemical, medicinal and nutraceutical properties of poppy seeds: a potential functional food ingredient. Functional Foods in Health and Disease, 11 (10): 522-547. https://doi.org/10.31989/ffhd.v11i10.836.

Baka, 2024. Haşhaş Tarımı ve Endüstrisi Fizibilite Raporu. (Web page: https://baka.gov.tr/assets/upload/dosyalar/hashas.pdf) (Date accessed: March 2025).

Baydar, H., 2009. Tıbbi ve Aromatic Bitkiler Bilimi ve Teknolojisi (Genişletilmiş 3.Baskı). Süleyman Demirel Üniversitesi Yayın No: 51 (ISBN: 975-7929-79-4) 347 pp.

Bulut, B., Z. Aydınlı & M. Türktaş-Erken, 2020. MSAP analysis reveals diverse epigenetic statuses in opium poppy varieties with different benzyisoquinoline alkaloid content. Turkish Journal of Biology, Vol. 44 (2): 103-109. https://doi.org/10.3906/biy-1911-69.

Dash, A.K., R.C. Pradhan, L.M. Das & S.N. Naik, 2008. Some physical properties of simarouba fruit and kernel. International Agrophysics, 22 (2): 111-116.

Gomez, K. A. & A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Ed., Wiley-Interscience.

Gümüşcü, A. & G. Gümüşcü, 2015. İklim değişikliği ve haşhaşın verim bileşenleri üzerine etkisi. Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi, 24 (1): 79-84. https://doi.org/10.21566/tbmaed.40626.

Güngör, O. & İ. Akıncı, 2024. Determination of Some Physico-Mechanical Properties and Critical Velocity of Opium Poppy Plant (Papaver somniferum L.) 'Ofis 1' (Blue). Tekirdağ Ziraat Fakültesi Dergisi, 21 (5): 1213-1221. https://doi.org/10.33462/jotaf.1480031.

Güngör, O., 2023. Haşhaş Bitkisi İçin Biçme Düzeni Parametrelerinin Belirlenmesi ve Elektronik Kontrollü Prototipinin Geliştirilmesi. Akdeniz Üniversitesi Fen Bilimleri Enstitüsü Tarım Makinaları ve Teknolojileri Anabilim Dalı, (Unpublished) Doktora Tezi, 97 s.

Hacıyusufoğlu, A.F., 2013. Laboratuvar Koşullarında Haşhaş Kapsül Toplama Sisteminin Geliştirilmesi. Adnan Menderes Üniversitesi Fen Bilimleri Enstitüsü Tarım Makinaları Anabilim Dalı, (Unpublished) Doktora Tezi, 120 s.

Hong, U.V.T., M. Tamiru-Oli, B. Hurgobin, C. Okey, A. Abreu & M. Lewsey, 2021. Insights into opium poppy (Papaver spp.) genetic diversity from genotyping-by-sequencing analysis. Scientific Reports (Sci Rep): ISSN 2045-2322 (online), 12 (111):1-15. https://doi.org/10.1038/s41598-021-04056-3.

Hope, E., M. Murphy, C. Hudson, L. Baxter & A. Gracie, 2020. Opium poppy capsule growth and alkaloid production is constrained by shade during early floral development. Annals of Applied Biology, 176 (3): 296-307.

İşler, N., 2024. Haşhaş Tarımı. Mustafa Kemal Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü Ders/Slayt Notları, 81 s.

Kara, M., 2012. Biyolojik Ürünlerin Fiziksel Özelikleri. Atatürk Üniversitesi, Ziraat Fakültesi, Ders Yayınları, No: 242, 327 s.

Kara, N., 2017. The effects of autumn and spring sowing on yield, oil and morphine contents in the turkish poppy (*Papaver somniferum* l.) cultivars. Turkish Journal of Field Crops, 22 (1): 39-46. https://doi.org/10.17557/tjfc.301829.

Mohsenin, N.N., 1986. Physical Properties of Plant and Animal Materials (2nd Ed. Revised). New York: Gordon and Breach Science Publications, 891 pp.

Neugschwandtner, R., G. Dobos, H. Wagentristl, T. Lošák, A. Klimek-Kopyra & H. Kaul, 2023. Yield and yield components of winter poppy (papaver somniferum l.) are affected by sowing date and sowing rate under pannonian climate conditions. Agriculture, 13 (5): 997-1008. https://doi.org/10.3390/agriculture13050997.

Özarslan, C., 2002. Physcial properties of cotton seed. Biosystems Engineering, 83 (2): 169-174.

Özlü, R.R. & M. Güner, 2016. Farklı nem düzeylerinde kanola tohumlarının fiziksel özelliklerinin belirlenmesi. Journal of Agricultural Faculty of Gaziosmanpaşa University (JAFAG), 33 (Ek sayı): 10-24.

Polyák, N.I. & Z. Csizmazia, 2016. New methodology for measuring the floating velocity of grain particles. Journal of Agricultural Informatics. 7 (2): 49-59.

Qabatty, A. & F.N. Alayunt, 2023. 'Domat' sofralık zeytin çeşidinde farklı hasat yöntemlerinin ve kısa süreli depolamanın meyve kalitesine etkileri. Journal of Agriculture Faculty of Ege University, 60 (2): 343-352. https://doi.org/10.20289/zfdergi.1249758.

Skalický, M., V. Hejnák, J. Novák, A. Hejtmánková & I. Stranska, 2014. Evaluation of selected poppy (papaver somniferum l.) cultivars: industrial aspect. Turkish Journal of Field Crops, 19 (2): 189-196. https://doi.org/10.17557/tjfc.54263.

TMO, 2017. Toprak Mahsülleri Ofisi, Haşhaş ile İlgili Genel Bilgiler Kataloğu Toprak Mahsülleri Ofisi Genel Müdürlüğü, Ankara. 13 s.

TMO, 2019. Toprak Mahsülleri Ofisi, 2018 Yılı Haşhaş Sektör Raporu Toprak Mahsülleri Ofisi Genel Müdürlüğü, Ankara. 13 s.

Widener, M., Y. Bar-Yam, A. Gros, S. Metcalf & Y. Bar-Yam, 2012. Modeling policy and agricultural decisions in afghanistan. Geojournal, 78 (4): 591-599. https://doi.org/10.1007/s10708-012-9453-y.

Zając, T., A. Oleksy & A. Klimek-Kopyra, 2012. Comparison of growth and productivity of the low morphine poppy papaver somniferum l. cv. mieszko depending on the sowing date. Acta Agrobotanica, 64 (3): 67-78. https://doi.org/10.5586/aa.2011.033.