

The variation in leaf morphological characteristics of carob (*Ceratonia siliqua* L.) in Al-Jabal Al-Akhdar region, Libya

Azeeza R Saad^{1*}, Ghalia T El Rabiai², Sabah H Lamlom¹

¹ Department of Botany, Faculty of Science, University of Omar Al-Mukhtar, Al-Bayda, Libya

² Department of Botany, Faculty of Science, University of Benghazi, Benghazi, Libya

Abstract

Carob tree, *Ceratonia siliqua* L. (family Fabaceae), is an evergreen endemic species growing wild in Al-Jabal Al-Akhdar area, Libya. A morphological study was conducted for *C. siliqua* from three different terraces in four areas of Al-Jabal Al-Akhdar (Karsa, Akfanta, Balagra, and Ras Al-Hilal) with different altitudes (90, 282, 623 and 684 m above sea level, a.s.l). The aim of this study was to compare how *C. siliqua's* morphological traits were affected by altitudinal gradients. Tree height, leaves length, width, size, color, leaflets length, width, size, and petiole length were studied. Tree height measurement from three different terraces was recorded and compared. Results showed that with increasing altitude above sea level, tree height, leaves length, width, size, leaflets length, width, size, and petiole length were decreased. The highest recorded height of *C. siliqua* during this study was 14.6 m. It was located Karsa region, while the Ras al Hilal area, was found lowest recorded height of about 3.5 m, in Akfanta, the largest leaf size of carob tree was recorded to be 180 cm², while in Ras Al Hilal, the smallest leaf size was recorded to be 100 cm². Petiole length reached 9 cm in Karsa and 5 cm in Ras al Hilal.

Keywords: Carob, *Ceratonia siliqua* L., morphological, elevation, altitude

Introduction

Green Mountain located in the northern part of Cyrenaica, also known as "Barqah," on the northeastern coast of Libya, is also known locally as "Al-Jabal Al-Akhdar" (Tashani, *et al.*, 2020) [1]. Al-Jabal Al-Akhdar is a hill with three progressively rising terraces, the highest of which is approximately 880 m a.s.l (El-barasi & Saaed., 2013) [4].

In the northeastern part of Libya, in the Al-Jabal Al-Akhdar area, south of the coastal belt, carob tree grows naturally. There is an average height above sea level of no more than 200 m. Positioned halfway between the first and third levels, the second terrace has an average elevation of 460 m above sea level. At its highest point, the third terrace is approximately 880 m above sea level. This level has a chilly winter climate, but most of the summer months are moderate (Azzawam, 1995) [2].

Carob trees (*C. siliqua*) are polygamous, thermophilous, dioecious and common leguminous tree species that are evergreen. The majority of carob trees can be planted in semiarid or subtropical regions and thrive in calcareous soils, ideally close to the sea. They have pinnately compound leaves with two to six pairs of oval leaflets. Carob trees can reach heights of 10 to 15 meters with roots that can reach a depth of 25 meters. It has a lifespan of over a century. In Mediterranean nations, carob is widely recognized for its aesthetic, nutritional, and therapeutic benefits (Battle & Tous, 1997; Khatib & Vaya., 2010; Lamlom & Abdalrasol., 2016) [6, 7].

The leaves are pinnate, alternating, and 10–20 cm long. They may or may not have a terminal leaflet. They are coriaceous, dark green and glossy on the outside, pale green on the inside, the leaflets are 3-7 cm long, ovate to elliptic, and in 4-10 normally opposite pairs. The leaves are sclerophyllous with a very thick single-layered upper epidermis, contain phenolic compounds in the large vacuoles, and are finely veined with tiny stipules and

slightly undulate margins (Mitrakos 1988; Atiya *et al.*, 2023) [1, 9].

This study aimed to compare how *C. siliqua's* morphological traits were affected by altitudinal gradients. (tree height, leaves length, width, size, color, leaflets length, width, size, and petiole length) of the Libyan carob, from three different terraces in four areas of Al-Jabal Al-Akhdar (Karsa, Akfanta, Balagra, and Ras Al-Hilal) with different altitudes (90, 282, 623 and 684 m above sea level, a.s.l).

Materials and Methods

1. Study Description

The study sites are Karsa, Akfanta, Balagra, and Ras Al-Hilal which are located in Al-Jabal Al-Akhdar area, Libya.

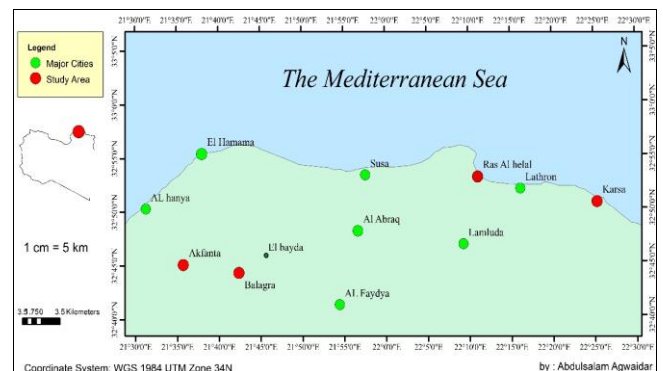


Fig 1: Study sites

2. Sample collection:

Ceratonia siliqua L. trees were collected from the study areas (Karsa, Akfanta, Balagra and Ras al Hilal). The specimens were identified using Libyan plants found in the *Silphium* herbarium at the Faculty of Science, Al-Bayda, Libya: Omar Al-Mukhtar University, Department of Botany.

The plant specimens were classified using the books of Flora Libya. The specimens were placed in the herbarium of Silphium. Throughout 2021–2023, frequent trips to the study area were made in the fall, winter, and spring. Prior to their collection, the plant samples were captured on camera. gathered plants while they were in bloom and bearing fruit. Considering that papers were changed every day, samples were dried for two weeks by the press and papers. The plant specimens were then adhered to the herbarium sheet. In the Silphium herbarium, the plant specimens were stored.

Tree heights

The triangulation principle and a clinometer were used to measure the heights of the trees. [CLINO Master Silva].

Leaf size estimation

To measure the plant leaf, it was placed on graph paper, its outline was drawn using a pen/pencil, and the surface area was expressed in square centimetres (multiply the number of full squares by 1 cm² and partial squares by 0.5 cm² and add them together).

3. Results

This study showed that tree heights factor directly affects the morphological characteristics of carob trees such as Tree height, leaf length, width, size, color, leaflets length, width,

size, and petiole length. The study showed that Karsa area, which is located on the first terrace, rises 90 m above sea level, it has the highest tree heights of carob plants among the four study areas, reaching a height of 14.70 m, and leaflets had an oval shape. Akfanta area, which is located on the second terrace, rises 282 m above sea level, and tree heights were up to 14.50 m. It also leaflets had an oval shape with smooth edges and were not hairy, but had a dark green color. Balagra area is located on the third terrace, rises 623 m above sea level, and tree heights were 10.35 m. It also leaflets had an oval shape with smooth edges and were not hairy and had a dark green color. Ras al-Hilal area, which is located on the third terrace and the highest area among the four study areas, rises 684 m above sea level, and tree heights were 5.89 m. The leaflets were also leathery in texture, smooth, non-hairy, and had dark green color.

Results showed that with increasing altitude above sea level, tree height, leaves length, width, size, leaflets length, width, size, and petiole length were decreased. The highest recorded height of *C. siliqua* during this study was 14.6 m. It was located Karsa region, while the Ras al Hilal area, was found lowest recorded height of about 3.5 m, in Akfanta, the largest leaf size of carob tree was recorded to be 180 cm², while in Ras Al Hilal, the smallest leaf size was recorded to be 100 cm². Petiole length reached 9 cm in Karsa and 5 cm in Ras al Hilal.

Table 1: The morphological characteristics of *C. siliqua* plants

Characters	Karsa	Akfanta	Balagra	Ras al Hilal
Tree heights (m)	14.6 ± 0.200 6.35 ± 0.1150	14.47 ± 0.1365 5.63 ± 0.1539	10.37 ± 0.1124 3.90 ± 0.1007	5.88 ± 0.1150 3.19 ± 0.0603
Leaf length (cm)	22 ± 2.00 15.6 ± 1.528	20.1 ± 1.353 15 ± 1.000	18 ± 1.000 13 ± 1.000	17 ± 1.000 11 ± 1.000
Leaf width (cm)	18 ± 1.000 11 ± 1.000	16 ± 1.000 11 ± 1.000	14 ± 1.000 10 ± 1.000	13 ± 1.000 10 ± 1.000
Leaf size (cm ²)	177 ± 1.000 168 ± 1.000	180 ± 1.000 162 ± 1.000	157 ± 1.000 152 ± 1.000	107 ± 1.000 100 ± 1.000
Leaf color	dark green	dark green	dark green	light green
leaflet length (cm)	8 ± 1.000 6.5 ± 0.551	7.7 ± 0.200 5 ± 1.000	7 ± 1.000 5 ± 1.000	6 ± 1.000 4.6 ± 0.1528
leaflet width (cm)	5.5 ± 0.1000 4.2 ± 0.252	5.3 ± 0.1000 4 ± 1.000	5 ± 1.000 4 ± 1.000	4 ± 1.000 3.7 ± 0.208
Leaflet size (cm ²)	24 ± 2.00 18.5 ± 1.76	22 ± 1.000 16 ± 1.000	22 ± 1.000 15 ± 1.000	18 ± 1.000 14 ± 1.000
Petiole length (cm)	9 ± 1.000 5 ± 1.000	8 ± 1.000 5 ± 1.000	7 ± 1.000 4.5 ± 1.000	6.3 ± 2.00 5 ± 1.000

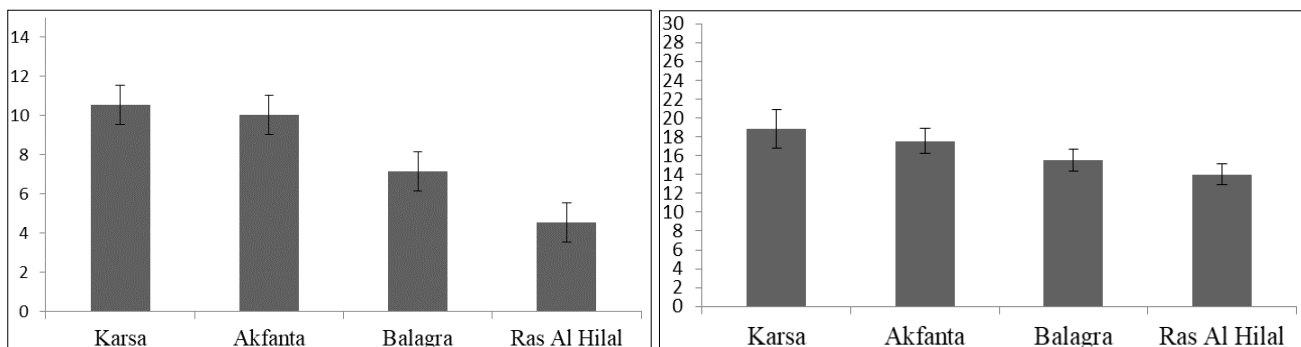


Fig 2: Plant length and leaf length of *C. siliqua* in study regions

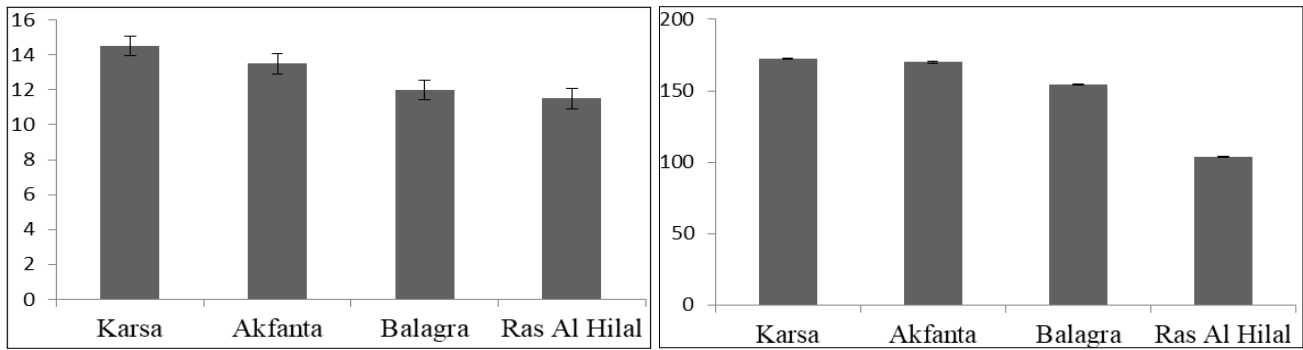


Fig 3: Leaf width and size *C. siliqua* in study regions

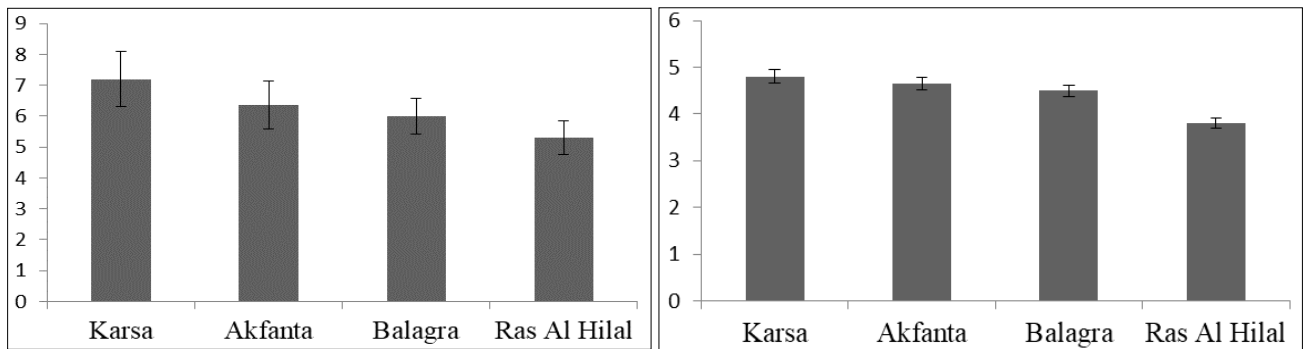


Fig 4: Leaflet length and width *C. siliqua* in study regions

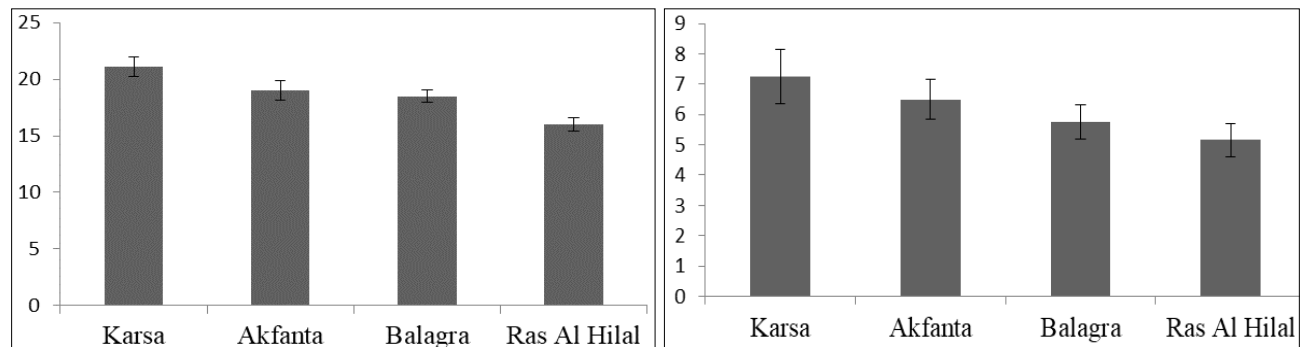


Fig 5: Leaflet size and petiole length *C. siliqua* in study regions

Statistical analysis: In order to compare the impact of altitudinal gradients on the morphological traits of *C. siliqua*, Minitab version 17 software was used to analyze the numerical values obtained from the various parameters measured and compute averages and standard deviations. The data's validity and variability were verified using one-way analysis of variance (ANOVA). The alpha level was set at 0.05 ($\alpha = 0.05$), and the means of each treatment were compared to each other using Tukey's test.

Discussion

The morphological and anatomical characteristics of trees can be greatly impacted by the scarce environmental resources and requirements that change with elevation (Puijalon & Bornette, 2006; Matesans *et al.*, 2010; Nicotra *et al.*, 2010; Nascimbene & Marini, 2015) [10].

Depending on the type of tree species, different morphological and anatomical traits may be seen along altitudinal gradients (Gercek *et al.*, 1998; Briceño *et al.*, 2000; Tiwari *et al.*, 2013; Topaloğlu *et al.*, 2016; Keles *et al.*, 2020) [5].

Liu *et al.*, 2020 [8], examined the leaf morphology structures of three distinct species *Potentilla fulgens* Wall, *Pedicularis*

densispica Franch., and *Epilobium amurense* Hausskn. Ex Hook growing along an elevation gradient (3,000–4,600 m). The findings demonstrated that in all three species, leaf length and width decreased with increasing altitude. With increasing elevation, each species' stomatal density rose. These results demonstrate that plants can reduce the size of their leaves in order to adjust to the environmental changes brought on by high elevation. This is in agreement with the current research.

References

1. Atiya RR, Abdalrasol EM, Lamom SH. The impact of altitude on seed germinability of libyan carob (*Ceratonia siliqua* L.) from Al-Jabal Al-Akhdar area. International Journal of Biology research, 2023;8:1-4.
2. Azzawam SM. Al-Jabal Al-Akhdar: A Study in Physical Geography. (In Arabic). Garyounis University, Benghazi, Libya, 1995, 139. (In Arabic).
3. Batlle I, J Tous. Cultivares autóctonos de algarrobo (*Ceratonia siliqua* L.) en Cataluña. Investigación Agraria, 1997;5(2):223-238.
4. El-Barasi YMM, Saaed MWB. Threats to plant diversity in the northeastern part of Libya (Al-Jabal Al-

- Akhdar and Marmarica Plateau). Journal of Environmental Science and Engineering. A,2013:2(1A):41.
5. Keles SO. The effect of altitude on the growth and development of trojan fir (*Abies nordmanniana* subsp. *equi-trojan* [Asch. & Sint. ex Boiss] Coode & Cullen) saplings. *Cerne*,2020:26(3):381-392.
 6. Khatib S, Vaya J. Fig, carob, pistachio, and health. In *Bioactive foods in promoting health*. Academic press, 2010, 245-263.
 7. Lamlom SH, Abdalrasol EM. Effects of various pre-sowing treatments on seed germination of carob (*Ceratonia siliqua* L.) from Al-Jabal Al-Akhdar area (Balagrae, Al-Baida, Libya). *IOSR Journal of Agriculture and Veterinary Science*,2016:9(09):16-24.
 8. Liu W, Zheng L, Qi D. Variation in leaf traits at different altitudes reflects the adaptive strategy of plants to environmental changes. *Ecology and Evolution*,2020:10(15):8166-8175.
 9. Mitrakos K. The botany of *Ceratonia*. Pp.209-218 in *Proceedings of the II International Carob Symposium* (P. Fito and A. Mulet, eds.). Valencia, Spain, 1988.
 10. Nascimbene J, Marini L. Epiphytic lichen diversity along elevational gradients: biological traits reveal a complex response to water and energy. *Journal of Biogeography*,2015:42(7):1222-1232.
 11. Tashani A, El-settawy A, Mohareb A. Effect of environmental conditions on wood properties of some tree species growing in Al-Jabal Al-Akhdar region, Libya, 2020, 205-215.