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THE IMPACT OF CLIMATE AND ENVIRONMENTAL CHANGES ON AGRICULTURE: CAROB SEED GERMINATION

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Abstract

There is a direct relationship between climate change and carob seed germination, particularly in areas where carob is native, such as Libya. It is important to study the germination process and response of carob seeds to the anticipated temperature increase. Information regarding the general effects of rising global temperatures on seed germination is currently scarce. By investigating the ecophysiology of germination performance in carob, a sclerophyllous Mediterranean species, this work seeks to close this information gap. The study concentrated on a wild carob genotype that was cultivated in Balagrae, Al-Bayda, in the Libyan region of Al-Jabal Al-Akhdar. The primary goals were to examine the germination responses of seeds from various individual trees at the same site and evaluate the impact of anticipated temperature change on carob seed germination characteristics. This study is the first to document the relationship between temperature rise in the Al-Jabal Al-Akhdar region and carob seed germination. However, given the eco-physiological features, more investigation is required to completely comprehend how carob seed germination reacts to projected temperature rise on a bigger scale. The consequences of rising global temperatures on seed germination in general are not well understood. We can forecast potential changes in flora as a result of climate change and improve our understanding of *C. siliqua's* distribution by gathering data on the factors influencing carob seed germination. It is acknowledged that carob is a natural species in the Mediterranean area. It is clear that several tree species with a broad regional distribution, such as carob, have evolved unique geographic variants. These differences correlate with physiological characteristics such growth season duration, photoperiod requirements, and resistance to cold, drought, and illnesses. These mutations have adapted to certain habitats through natural selection throughout time, which makes them less successful when transferred to other ecosystems. Via the seeds, these genetic variations are inherited. In the event that local seeds are unavailable, it is therefore advantageous to use seeds from a source close by or from a region with a comparable climate and latitude. Furthermore, three different trees' seeds from the same site were the subject of our investigation. Expanding the study to include more trees from both the same and different places might be beneficial. As seen by variations in growth rate, wood density, turpentine yield, and other characteristics, even trees of the same species growing near to one another can differ genetically and physiologically. The fact that these characteristics are frequently passed down through seeds to progeny highlights how crucial it is to choose seed trees for nursery planting with care. Superior trees usually produce heterozygous offspring with a variety of advantageous features.

Keywords

Climate change, environmental changes on agriculture and carob seed germination.

INTRODUCTION:

Climate change and carob seed germination:

Temperature influences the rate and timing of seed growth, which is a critical step in the germination process. It has been noted that until the temperature reaches a range of 30-35°C, germination speed tends to rise. Temperature variations in the surrounding environment also affect when seeds germinate, acting as a regulatory mechanism for dormancy in different seed populations. This rule enables seeds to evade adverse environmental circumstances when establishing seedlings. The range of temperatures at which particular plant seeds can germinate is determined by cardinal temperatures, which include the minimum, optimal, and maximum temperatures. We can determine the ideal time and place for growth as well as the species' spreading zone by determining the cardinal temperatures of each type of plant. The lowest temperature denotes the point at which germination is not possible, and the highest temperature denotes the point at which germination is not possible. Conversely, the temperature that facilitates the fastest rate of germination is referred to as the ideal temperature. Ideal temperatures promote general plant growth in addition to speedy seed germination. It is crucial to remember that different species have varying minimum, optimal, and maximum temperatures for seed germination; temperate zone species often have lower values than tropical species. Furthermore, the temperature at which seeds germinate can vary based on the origin of the seeds. The ideal germination temperature can vary throughout plants in the same species. The rate of seed germination can be hampered by temperature deviations, either above or below the ideal range. It is important to note that depending on the location, higher temperatures can affect ecosystems in different ways. Positive results are anticipated in areas where low temperatures now prevent seed from germinating. These effects will be more pronounced in places where high temperatures and low soil moisture inhibit seedling establishment. Regretfully, one of the least understood processes is how high temperatures stress plants [28].In Mediterranean climates, temperatures between 15°C and 20°C are ideal for germination [29, 4].But the weather is shifting; temperatures are rising and are expected to rise even faster in the future [27].Many modeling studies have been started to forecast potential effects on plant dispersal in light of the anticipated large impact these future climate changes are projected to have on biodiversity [19]. According to [10], North Africa is especially susceptible to the consequences of climate change. According to model forecasts, North Africa will have an average yearly temperature increase that is greater than the global average [1]. It is anticipated that rising temperatures brought on by climate change will diminish the amount of land suitable for agriculture in this area, shorter growing seasons, and lower crop yields. The most important effects of climate change in North Africa (Morocco, Algeria, Tunisia, Libya, and Egypt) are probably going to be on agriculture and water resources due to inherent uncertainties and worldwide climate predictions. Mediterranean basin countries frequently deal with issues related to water resources, agriculture, and the environment [25].

In the nations around the Mediterranean basin, a multitude of human activities, including fires, overgrazing, timber cutting, and unchecked development, have resulted in habitat loss [18]. Scientists have stressed that protecting the natural ecosystems in this area is crucial because they can play a major role in addressing the issue of food scarcity. The Mediterranean region has a dry climate with noticeable seasonality, with long, warm, and dry summers and moderate, rainy winters. This region's plant biodiversity is threatened by a number of climatic factors, such as dryness, high rates of evaporation, warm summer and cold winter temperatures, as well as fairly high light intensity and restricted soil nutrient availability [24]. The Mediterranean's extreme highs and lows can severely restrict plant development, affecting both productivity and spread [13]. Furthermore, because of leaf warming, high summer temperatures might result in a drop in the net photosynthetic rate [24]. It is yet unclear how climate change may affect germination in the Mediterranean region due to its complexity [9].Since germination is predicted to benefit from global warming in colder places, most research has concentrated on these areas [12, 31, 2, 11].

The wide range of Mediterranean ecosystems is currently seriously threatened by climate change. The flora-ecosystems of the Mediterranean region are particularly sensitive to the effects of global warming because endemic species are particularly prone to extinction, particularly in places with high rates of endemism. Thus, researching the responses of Mediterranean indigenous plants to temperature increases may yield important information for preserving the region's botanical variety. Studies have revealed that carob seed germination is most successful at temperatures of about 25°C [8] and 27.5°C [17]. Nonetheless, [20] discovered no noteworthy variations in the percentages of germination over the range of temperature treatments (10, 15, 20, and 25°C) examined. In spite of this, it's important to remember that the study's temperature treatments all varied from low to ideal levels. Carob is grown extensively in North America and several Mediterranean nations, including Cyprus, Greece, Portugal, Italy, Spain, Lebanon, Southern Jordan, Syria, Turkey, Egypt, Libya, Tunisia, and Morocco [15] Robbs are a tropical plant that have adapted well to Mediterranean temperatures.

According to [5], the carob tree used its deep-rooted habit and xerophilous leaves to prevent water stress. [26] found that C. siliqua was the best species for restoration during periods of water scarcity. The Al-Jabal Al-Akhdar region, which includes Al-Wasita, Agfentta, Wadi Kouf, Al-Hania, Al-Hamama, Omar Al-Mukthar, Messa, Al-ghariqa, and North of Labraq, is thought to be home to a significant number of indigenous species that include carob. All of Al-Jabal Al-Akhdar's natural habitats are home to carob trees, which can be found growing either as pure populations or in mixed woodlands with *Pinushalepensis, Cupressus sempervirens, Juniperus phoenicea*, and *Oleaeuropaea* L. var. oleaster. Pods, also called carob legumes, are frequently made into flour and mixed with other cereals for human use, or they are utilized as animal feed. These legumes are superior to oats and comparable to barley in terms of nutritional value as cattle feed due to their high sugar and protein content [7]. Moreover, legumes are used to make carob syrup, health foods (like a chocolate alternative), and medications (like diuretics and laxatives) [6,7]. They can also be used as a cheap source of carbohydrates to produce ethanol. The locust-bean gum, also referred to as carob or *locomanane polysaccharides*, is a compound found in the seeds of the carob tree [5]. This substance is an important thickening and stabilizing ingredient used in the paper, textile, petroleum, and food processing industries. Because of its high viscosity, carob gum can be used in place of some other gums [3].

MATERIALS AND METHODS:

The investigation was carried out at Balagrae, which is 522.5 meters above sea level and has coordinates of 32' 73"–32' 77"N 21' 70"–21' 68"E. This area is about 10 kilometers south of Al-Baida. The selection of this location was based on its varied forest and close proximity to the campus of Omar Al-Mukthar University. The study was conducted at the graduate studies lab of the Science Faculty's Botany Department at Omar Al-Mukthar University in Al-Beida, Libya.

Climatic measurement:

The weather of Balagrae is characteristic of the Mediterranean, with hot, dry summers and moderate, damp winters. The annual average temperature is between 11.9 and 21.4°C. The average temperature in January is between 6.3 and 13.5°C, while in July, it is higher than 16.8°C, with a maximum recorded temperature of 27.5°C. We acquired climate data from the Al-Baida meteorological center for the years 1999–2015.

Effects of different temperatures on seed germination:

The second experiment's main goal was to investigate how various consistent temperatures affected the germination of carob seeds from the particular study location. Following our pre-sowing treatments, we decided to mechanically scarify the seeds and then immerse them in distilled water for a whole day. To increase the germination rate, the seeds were also sanitized in an aseptic environment. The temperature-controlled incubators with six distinct temperature ranges (20, 25, 30, 35, 40, and 45°C) were used for the germination tests, which were carried out in complete darkness. We intended to completely explore the effect of temperature on seed germination by carrying out the germination tests in the dark, excluding any possible contribution from other variables like light. Three duplicates of ten seeds from each tree were placed in a perfectly randomized pattern for each temperature treatment. Two sheets of filter paper (Whatman no. 1) were put in glass Petri dishes with a 15 cm diameter for the germination testing. The seed was deemed to have germinated when its radicle reached a minimum length of 0.5 mm. Every 24 hours, the number of germinated seeds was tallied until no more germination was seen. Each Petri dish was filled with enough distilled water for the germination tests, and the filter papers were frequently moistened to guarantee uniform saturation. The trials lasted for a minimum of three to four weeks and a maximum of thirty days, or until the seeds stopped germination.

Measurements of root and shoot lengths:

To measure the lengths of the roots and shoots, seedlings were plucked from each petridish and separated into shoot and root fractions. It was measured in millimeters using a measuring scale.

Germination parameters:

We measured the following germination parameters: As previously mentioned, the mean germination time (MGT) and the germination percentage (%) were computed.

Measurements of root and shoot lengths: To determine the lengths of the roots and shoots, seedlings were removed from each petridish and separated into fractions of the shoot and root. It was measured in millimeters using a measuring scale.

To measure the length of a seedling, multiply its root length by its shoot length. The fresh and dry weight of each seedling were measured. First, the shoot and root were wrapped in filter paper and weighed. Next, they were dried using a high-temperature oven method (130°C for 1 hour; ISTA 2003) and weighed again to determine the dry weight. These were expressed in grams and measured with a digital balance.

Measurements of fresh and dry weight of seedlings:

The seedling's fresh weight is equal to its fresh root weight plus its fresh shoot weight, however the -Seedling dry weight is equal to the sum of the root and shoot dry weights.

Content of moisture:

Seed moisture content was calculated using the formula below, which was provided by (ISTA 2003): Fresh weight - Dry weight / Fresh weight X 100 equals the moisture percentage.

RESULTS:

Table 1 provides information on temperature conditions, individual trees, and their combined effect on several germination parameters of the carob seeds under investigation. It also provides a detailed analysis of the effect of elevated temperatures on carob seed germination. Temperature circumstances had a highly significant effect on all of the qualities indicated, according to a two-way analysis of variance ($P<0.0001$). An examination of Table 1 and Figure (1a) indicates that 84.7% of the seeds cultivated at 20°C germinated. There was a substantial difference between the two temperature settings. Seeds produced at 25°C had the highest germination rate (95.9%), followed by seeds cultivated at 30°C with 91.3%. At 35°C, the proportion of seeds that germinated increased to 77.3%, while at 45°C, the lowest percentage (17.5%) was observed. On the other hand, 52.1°C produced a germination percentage. According to Table 1 and Figure 1b, seeds germinated at 45°C (8.95 days MGT) had the longest Mean Germination Time (MGT), followed by seeds cultivated at 40°C (7.80 days MGT), with no discernible variations between the two temperature settings. At 25°C, the MGT was the shortest (2.42 days), and at 30°C, it was the longest (3.60 days), with notable variations across the two temperature treatments. There were no appreciable variations in the shortened MGT values of 5.20 and 5.57 days, respectively, between seeds cultured at 35°C and 20°C.

The seeds grown below 35°C had the maximum shoot fresh weight of 0.26 g, according to Table 1, 2, and the figures. The seeds produced at 30°C, 25°C, and 20°C had weights of 0.25 g, 0.24 g, and 0.22 g, respectively. There were no significant differences between the shoot fresh weight at 20°C and 25°C, however there was a difference between the shoot fresh weight at 35°C and 25°C. At 40°C, the lowest fresh weight of 0.05 g was seen in the shoots. Conversely, the greatest shoot dry weight of 0.049 g was recorded at 30°C, and was then followed by 0.046 g at 35°C, 0.045 g at 20°C, and 0.031 g at 25°C. Interestingly, there was a substantial change in shoot dry weight between 25°C and 30°C, but not between 30°C and 35°C or between 30°C and 20°C. At 40°C, the lowest shoot dry weight of 0.010 g was recorded.

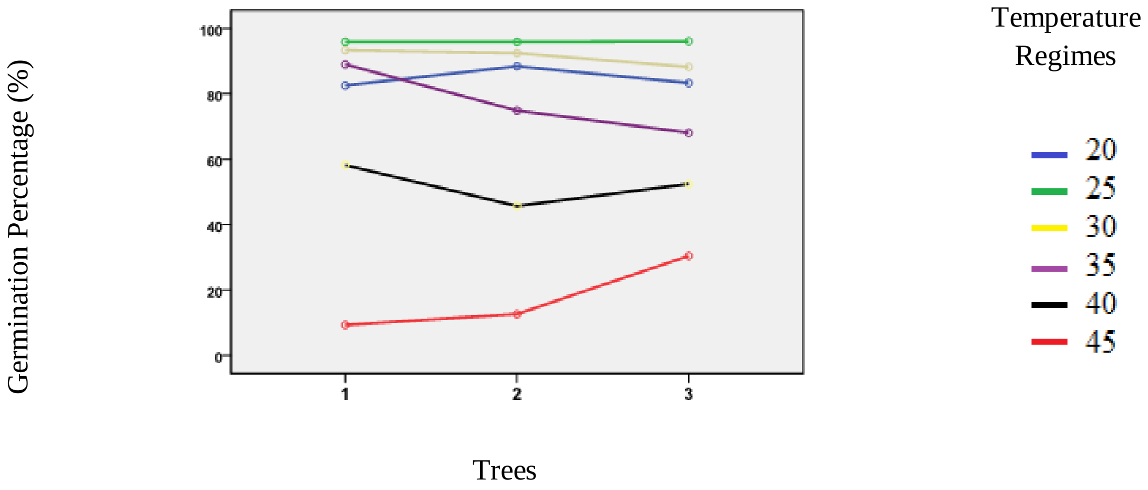
Table 1: The effects of different temperature regimes, individual trees, and their interaction on Germination %, Mean Germination Time, Speed Germination, of *Ceratonia siliqua* seeds.

Source of variation	Germination %	Mean Germination Time	Speed Germination	Mean Daily Germination	Peak Value	Germination Value
Temperature regimes						
20	84.7±0.9c	5.57±0.28b	1.87±0.10c	15.2±1.0c	15.7±0.9c	246.3±32.4c
25	95.9±0.1a	2.42±0.12d	4.29±0.19a	35.2±1.9a	39.5±1.8a	1409±142a
30	91.3±0.8b	3.60±0.25c	2.97±0.18b	23.6±2.2b	24.6±2.3b	622.0±111.0b
35	77.3±3.7d	5.20±0.45b	1.62±0.21d	11.7±1.9d	12.2±2.1d	175.1±53.1c
40	52.1±3.4e	7.80±1.12a	1.15±0.11e	9.9±1.1d	9.9±1.1de	108.1±20.3cd
45	17.5±3.4f	8.95±1.09a	1.03±0.16e	6.2±1.0e	6.8±1.0e	50.1±16.5d
P value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Trees						
T 1	71.4±7.5a	4.28±0.29b	2.33±0.22a	19.2±2.2a	20.8±2.5a	489±106a

T 2	68.3±7.4a	5.99±0.84a	2.16±0.34b	16.4±2.7b	17.7±3.1b	427±116a
T 3	69.8±5.5a	6.50±0.78a	1.98±0.32c	15.3±2.9b	15.9±3.0b	389±152a
P value	0.2331	<.0001	0.0004	0.0049	0.0005	0.3683
Tem*tree (p value)	<.0001	<.0001	<.0001	0.0006	0.0003	0.0397
R2	0.9768	0.8903	0.9749	0.9299	0.9466	0.8922

Values represent (mean ± standard error). Mean values within column followed by the same letters are not significantly (α = 0.05, Two-way ANOVA).

The effects of temperature regimes, individual trees and their interaction on germination percentage (a):



Mean germination time (b) of *C. siliqua* seeds.

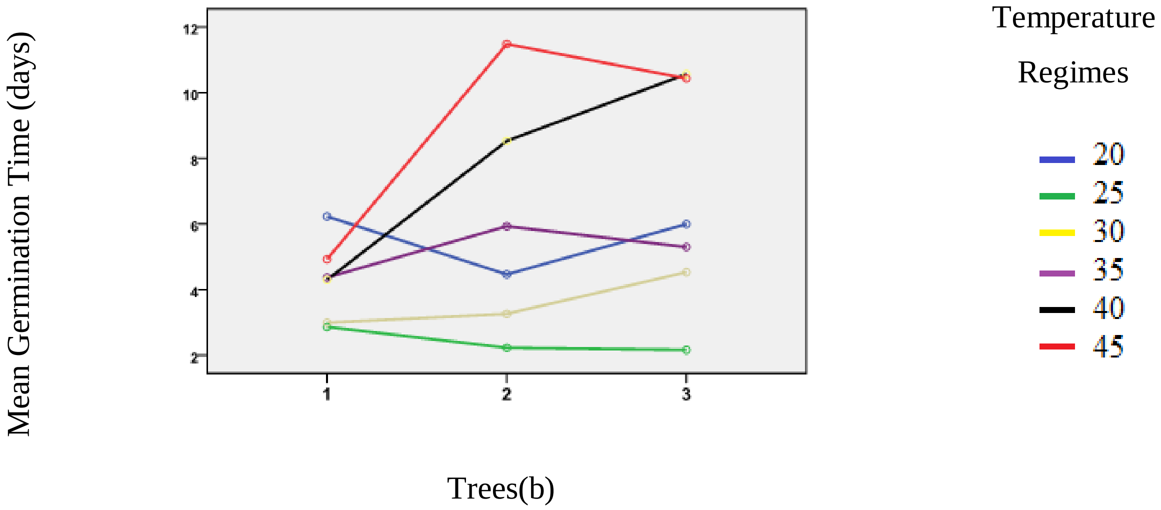


Figure 1(a and b). The effects of temperature regimes, individual trees and their interaction on germination percentage (a) and mean germination time (b) of *C. siliqua* seeds.

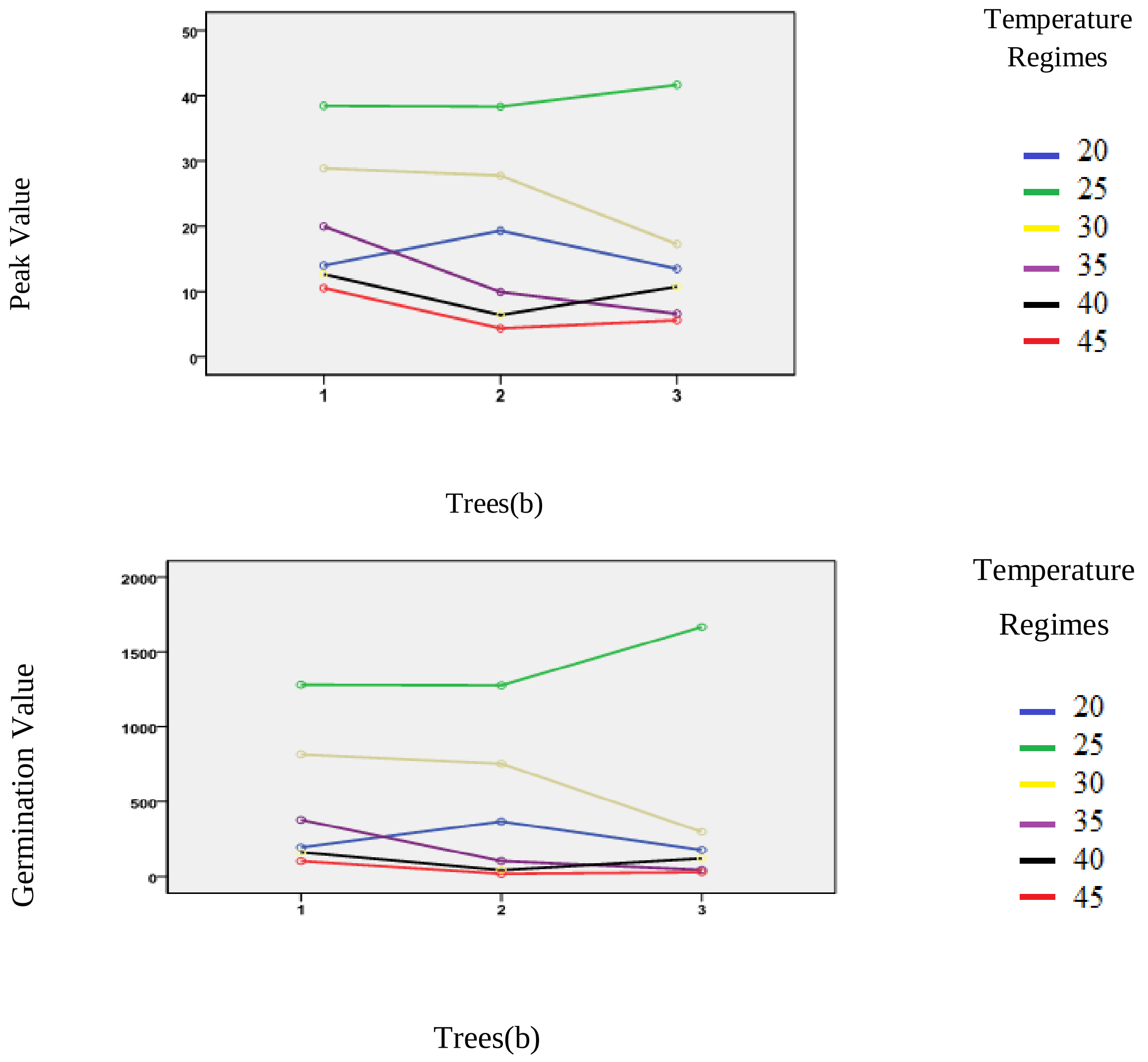
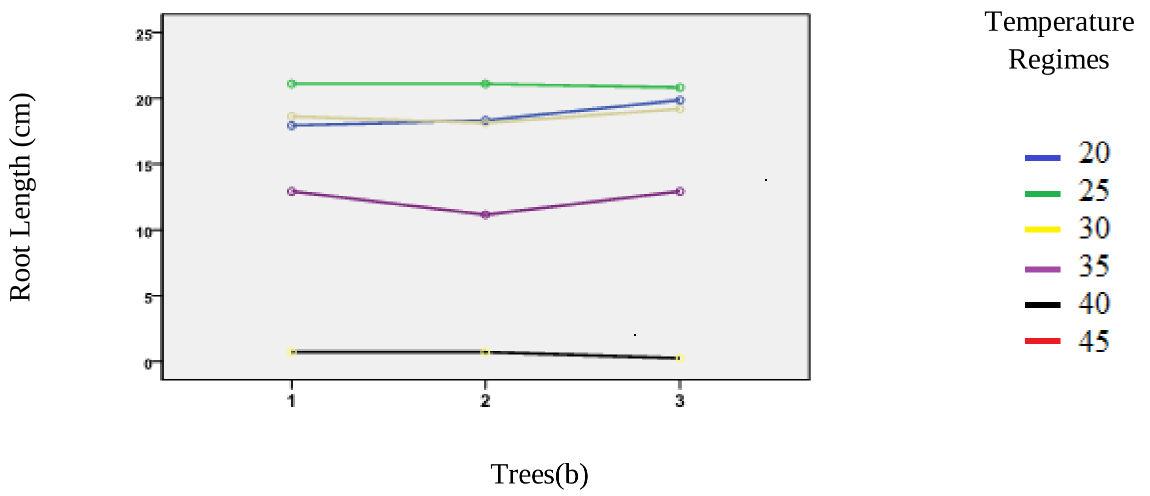


Figure 2. The effects of temperature regimes, individual trees and their interaction on peak value (a) and germination value (b) of *C. siliqua* seeds.



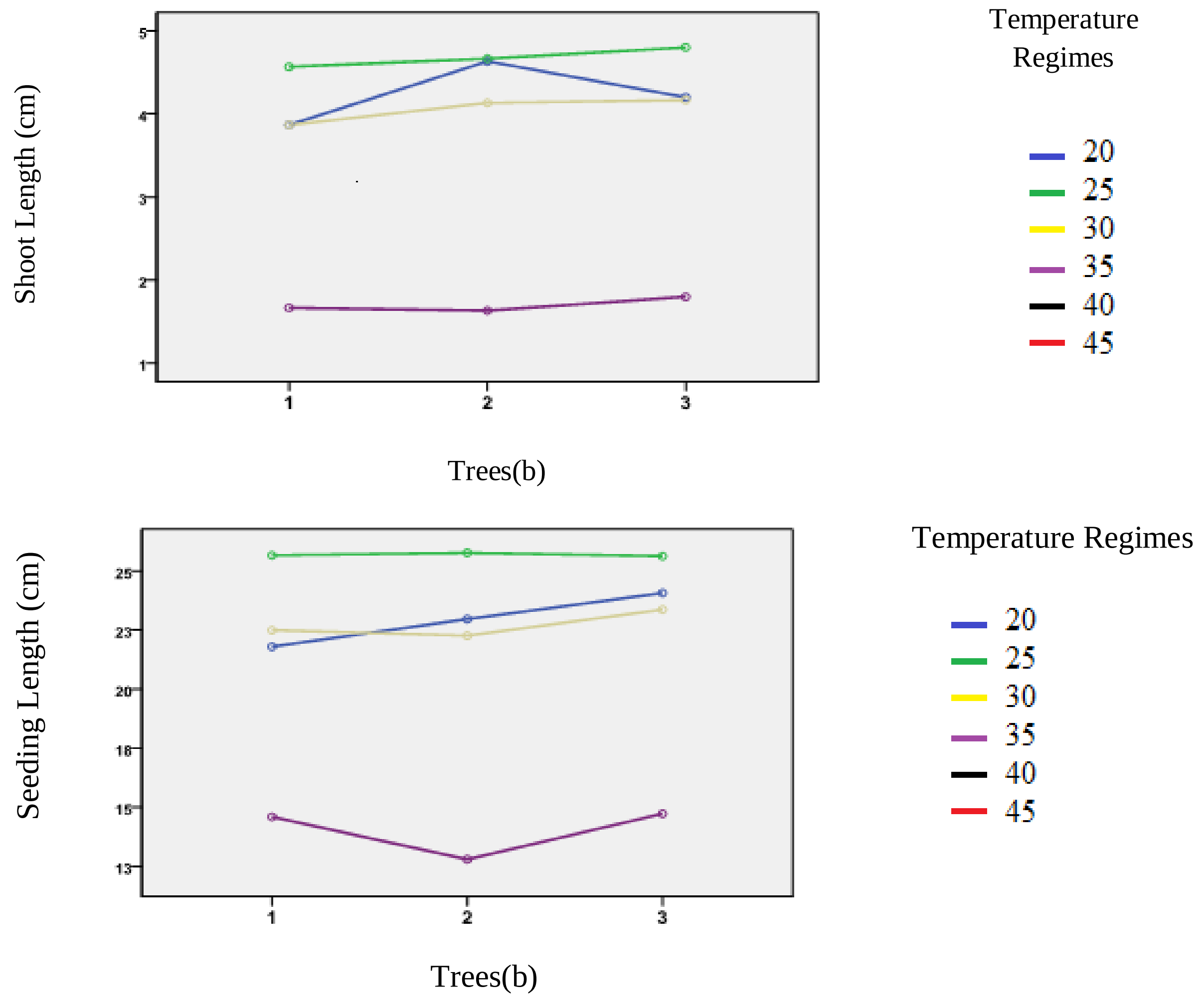


Figure 3. The effects of temperature regimes, individual trees, and their interaction on (a) root length, (b) shoot length, and (c) seedling length of *C. siliqua* seeds.

Figure 5: *C. siliqua* seeds germinated at temperature 25°C.

Figure 4. *C. siliqua* seeds germinated at temperature 20°C.

Figure 7: *C. siliqua* seeds germinated at temperature 35°C.

Figure 6. *C. siliqua* seeds germinated at temperature 30°C.

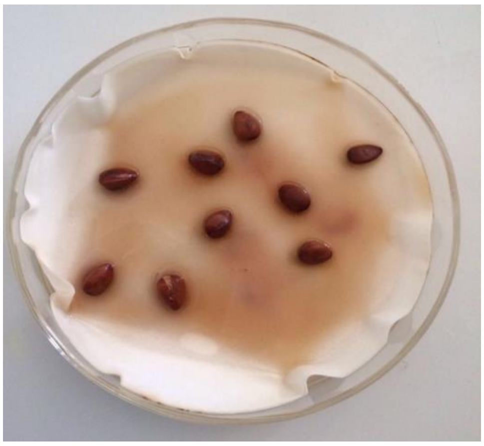


Figure 9: *C. siliqua* seeds germinated at temperature 45°C.

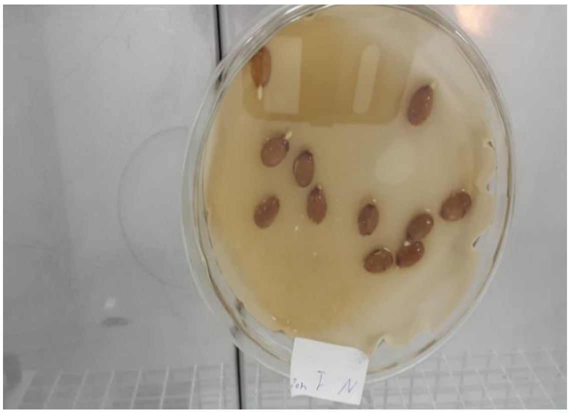
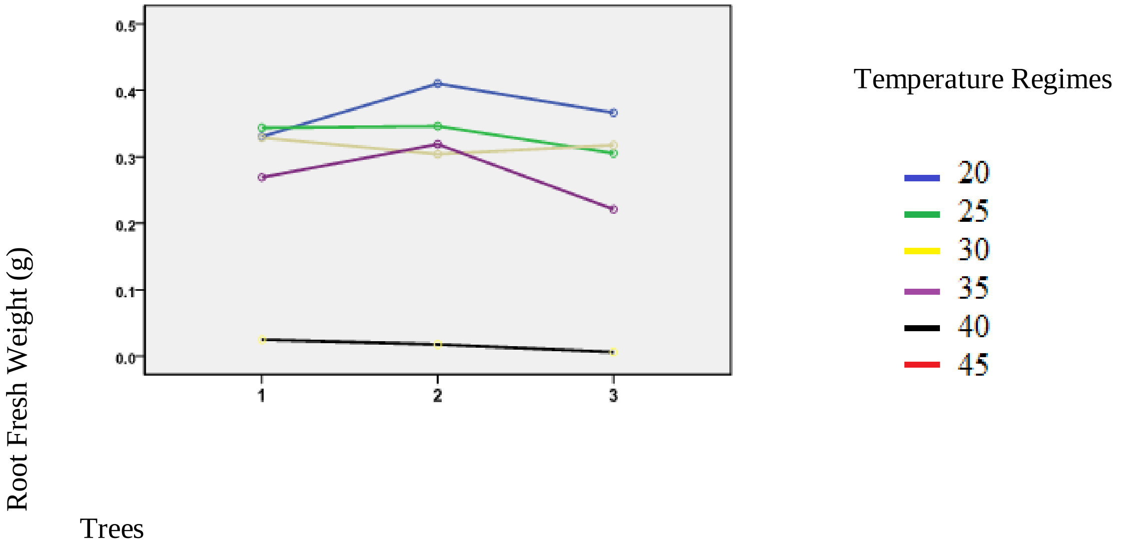


Figure 8. *C. siliqua* seeds germinated at temperature 40°C.



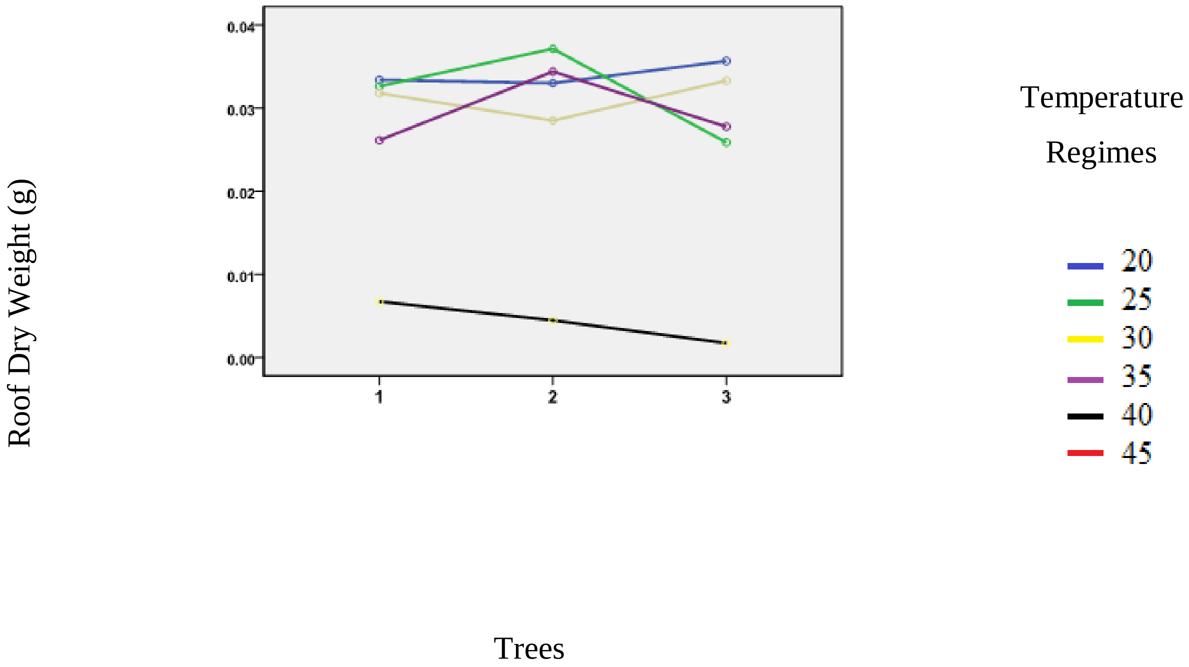
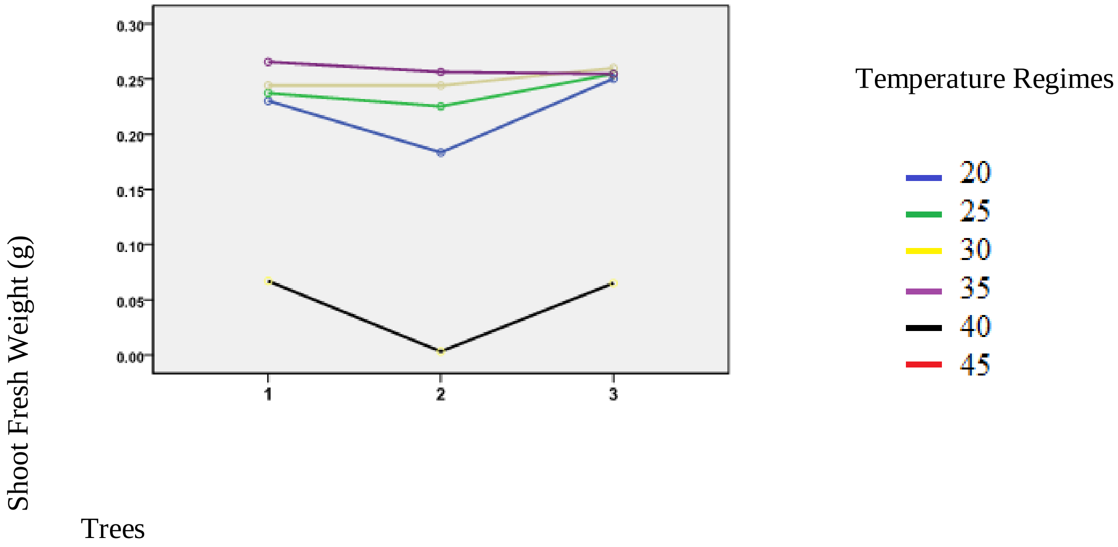


Figure 10. The effects of temperature regimes, individual trees, and their interaction on (a) root fresh weight and (b) root dry weight of *C. siliqua* seeds.



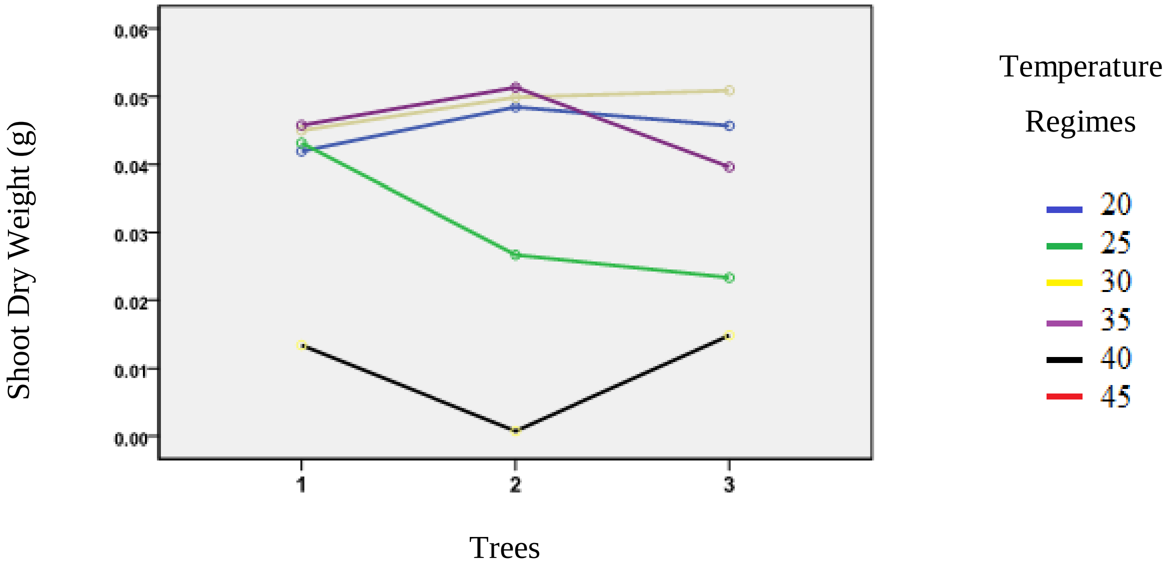


Figure 11. The effects of temperature regimes, individual trees, and their interaction on (a) shoot fresh weight and (b) shoot dry weight of *C. siliqua* seeds.

Table 2: The effects of different temperature regimes, individual trees, and their interaction on seedling fresh weight, seedling dry weight, root moisture, shoot moisture, seedling moisture, and vigour of *Ceratonia siliqua* seeds.

Source of variation	Seedling fresh weight (g)	Seedling dry weight (g)	Root moisture%	Shoot moisture%	Seedling moisture%	Vigour index
Temperature regimes						
20	0.590±0.014a	0.079±0.002a	90.6±0.6a	78.7±1.9b	86.5±0.4a	1945.7±63.5b
25	0.571±0.005ab	0.063±0.004b	89.8±0.2a	85.9±1.3a	89.0±0.7a	2447.0±20.9a
30	0.566±0.009ab	0.080±0.003a	90.1±0.4a	80.5±0.6b	85.9±0.4a	2073.5±45.9b
35	0.529±0.028b	0.075±0.005a	88.3±1.6a	82.2±1.2ab	85.6±0.9a	1087.0±61.3c
40	0.061±0.012c	0.014±0.003c	73.9±2.2b	78.7±3.1b	77.8±2.5b	-
45	-	-	-	-	-	-
P value	<.0001	<.0001	<.0001	0.0169	<.0001	<.0001
Trees						
T 1	0.468±0.052a	0.064±0.006a	86.5±2.1a	81.8±1.3a	85.2±1.0a	1901±126a
T 2	0.462±0.059a	0.063±0.008a	87.8±1.6a	79.5±1.7a	84.7±1.3a	1879±171a
T 3	0.460±0.054a	0.059±0.007a	85.3±2.1a	82.8±1.8a	85.1±1.7a	1884±168a
P value	0.8738	0.3882	0.2135	0.2322	0.9440	0.9134
Tem*tree (p value)	0.1010	0.0075	0.7528	0.3293	0.9456	0.0288
R2	0.9694	0.9303	0.8118	0.4738	0.5769	0.5769

Values represent (mean ± standard error). Mean values within column followed by the same letters are not significantly (α = 0.05, Two-way ANOVA).

DISCUSSION:

Temperature is one of the most important factors in the germination process of seeds. However, different species and cultivars have distinct ideal temperature ranges for germination [22]. Temperature has a complex effect on seed germination since it influences the process differently at each stage and is regulated by other factors [16].[23] established that three physiological processes involved in seed germination are influenced by temperature. First of all, temperature and moisture content determine how quickly seeds deteriorate. Second, the rate at which damp seeds break their dormancy is influenced by temperature. Finally, for seeds that are not dormant, temperature controls the rate of germination. As a result, the way that different plant species react to high temperatures depends on the degree of temperature increase, the length of the temperature increase, and other factors. Temperature has a major impact on seed germination; a rise in temperature between the base and ideal temperatures increases the percentage and pace of germination. On the other hand, temperatures that are higher than ideal can lower the percentage of germination [21].

Under certain conditions, plants cultivated at higher temperatures also yield lower-quality seeds with a decreased capacity for germination and growth. Plants' complex ability to tolerate high temperatures is determined by both their genetic make-up and the surrounding environment (Zróbek-sokolnik, 2012). The findings of our study show that a number of germination metrics, including germination value, speed of germination, mean daily germination, mean germination duration, peak value, and germination percentage, were all highest at 25°C and lowest at 45°C. Furthermore, at 25°C, root, shoot, and seedling lengths were longest, and at 40°C, shortest. At 25°C and 40°C, respectively, the values of shoot moisture%, seedling moisture%, and seed vigour index peaked. But as seeds could not germinate into seedlings at 40°C, the minimal seed vigour index was recorded at 35°C. At 20°C and 40°C, respectively, the values of root fresh weight, root dry weight, root moisture percentage, and seedling fresh weight were highest. The dry weight of shoots and seedlings reached their highest at 30°C and their minimum at 40°C. Among the germination characteristics, only shoot fresh weight displayed the maximum value at 35°C and the lowest value at 40°C. Consequently, the germination of carob seeds at various temperatures revealed that the ideal range of 25–30°C facilitates the successful germination of seeds for C. siliqua. This result is consistent with earlier research [8, 17] which found that 25°C and 27.5°C, respectively, are the ideal temperatures for carob seed germination. Our research indicates that high temperatures (40°C and 45°C) hampered the germination process by causing cell death and harm to the developing embryo.

Our research revealed that carob seedlings' root and shoot growth was unaffected by temperature changes between 30 and 35°C. At 40°C, however, there was a decrease in recorded germination parameters, such as shoot and root growth. Moreover, at 45°C, seeds could not develop into full seedlings. High temperatures have also been linked to a considerable drop in seed germination and vigour index.

CONCLUSION:

The outcomes unequivocally show how temperature affects the germination of carob seeds. Our work is a first step toward a better understanding of the relationship between incubation temperature and carob seed (*C. siliqua*) germination. 25–30°C was shown to be the ideal range for germination, but 40–45°C was associated with lower germination rates. Because there were fewer trees employed in this study, care should be taken when interpreting the results. To further investigate this relationship, larger sample sizes from various places should be included in future research. To verify the outcomes of laboratory trials, field research is required.

Based on current research, researchers may recommend some following future recommendations:

Long-term Monitoring: Establish long-term monitoring programs to track climate variables (temperature, precipitation patterns, humidity, etc.) and environmental changes (land use, soil quality, biodiversity loss, etc.) in regions where carob trees are cultivated. This data can provide insights into trends and correlations between climate/environmental factors and carob seed germination success.

Experimental Studies: Conduct controlled experiments to simulate future climate scenarios and assess their impact on carob seed germination. Manipulating factors such as temperature, water availability, and soil conditions can help understand the thresholds and sensitivities of carob seeds to climate change.

Genetic Studies: Investigate the genetic diversity of carob tree populations to identify traits associated with climate resilience, including seed germination under stress conditions. Understanding the genetic basis of adaptation can inform breeding programs aimed at developing more resilient carob varieties.

Microbial Interactions: Explore the role of microbial communities (e.g., mycorrhizal fungi) in mediating carob seed germination responses to environmental stressors. Investigating microbial interactions can uncover potential mechanisms for enhancing seedling establishment and resilience in changing environments.

Remote Sensing Techniques: Utilize remote sensing technologies (e.g., satellite imagery, drones) to assess spatial and temporal variability in carob tree phenology, vegetation health, and environmental conditions. Remote sensing data can complement field observations and provide a broader perspective on landscape-scale changes affecting carob cultivation.

Modeling Approaches: Develop predictive models that integrate climate, soil, and landscape data to forecast future changes in carob seed germination dynamics. These models can help identify regions at risk of declining germination success and inform adaptation strategies for sustainable carob production.

Stakeholder Engagement: Engage with local communities, farmers, and policymakers to raise awareness about the importance of preserving carob genetic resources and adopting climate-smart agricultural practices. Collaborative initiatives can promote knowledge exchange, capacity building, and collective action towards mitigating the impacts of climate change on carob cultivation.

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