Eco-geographic Study of Mahaleb (Prunus Mahaleb. L) in the Middle and Northern Parts of the Eastern Mediterranean

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Eco-geographic study of Mahaleb (*Prunus mahaleb*. L) in the middle and northern parts of the eastern Mediterranean

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Abstract

Background: Mahaleb still exists in most of the eastern Mediterranean forests associated with Cilician fir (Abies cilicica) and Lebanon cedar (Cedrus libani). However, there is an importance of conservation of its germplasm in hereditary banks due to their degradation in natural habitats, as well as there is growing interest in expanding Mahaleb cultivation due to its low requirements and endurance of harsh environments.

Methods: The study used the approaches of the autecology concepts to study Mahaleb in situ. The field surveys have been conducted on an investigated homogeneous area of about 100m^2 to 400m^2 as a (relevé area).

Results: Mahaleb occurs in its habitat in isolated individuals form and fragile structures of populations that were largely believed to have been in clumped or linear populations. The spatial distribution is restricted to small isolated zones in half-open, treeless or rocky outcrops areas of deciduous forests or rugged areas of barren mountains. The root sprouting seems to be the dominant mode of recruitment. However, all sites showed missing age classes that may indicate human infringement or the failure of recruitment in some years. The spatial distribution showed that Mahaleb exists in different environmental and climatic conditions regarding soil, landscape, rainfall, temperature. This can be attributed to its possession of genetic capabilities that enable it to adapt to varying environmental conditions in addition to the presence of different genotypes or higher taxa such as subspecies or even it may reflect the differences of environmental resilience inside some species themselves.

Conclusions: this reflecting Mahaleb's high ability to withstand environmental, thermal, and water stresses. Notable, strong, long roots were found at different depths of soils, some within the joints of the rocks, and this strengthens its role in protecting soil conservation. The geo-distribution of Mahaleb suggests different genotypes or higher taxa such as subspecies or even the differences of environmental resilience inside some species themselves.

It is also necessary to predict new potential areas for growth Mahaleb in the eastern Mediterranean to increase production either by introducing its cultivation in unconventional areas or by enhancing its productivity in the areas currently cultivated, which appears to be an important issue soon.

Keywords: Prunus mahaleb, eco-geographic, drought, genetic erosion, Mediterranean.

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Background

East Mediterranean region and Western Asia countries are considered the origin habitat of Mahaleb (*Prunus mahaleb* L., *Cerasus mahaleb* L. Mill., mahleb cherry or St. Lucie cherry EN., mahlab Arb.) (Zohary 1962; Ruiz, 1989; Rallo 1995; Scholz and Scholz 1995; Blanca and Diaz 1999; Katzer 2002). Besides, it is adjudged to be native in northwestern Europe or at least it is naturalized there (National Research Council 1991). The occurrence of small and spatially isolated populations in Switzerland forms the northern range edge that can Mahaleb reaches (Kollmann and Pflugshaupt 2005). The isolation of these old rare species is often the result of environmental change (Huenneke 1991) such as climate cooling that followed the warmest time of the post-glacial period (Burga and Perret 1998; Kollmann and Pflugshaupt 2005). Many studies consider Mahaleb to be one of the ancestors of cherry, where in many countries; it is used as seedling rootstock to grafting sweet cherry (*P. avium* L.) and sour cherry (*P. ceracus* L.). It is considered a strong rootstock due to its tolerance to drought and high calcium carbonate content in the soil (Nabulsi 2004); it is also found in most well-drained soils (Guitian 1993) and poor soils on open rocky slopes as well as in sunny or partially sunny places (Bean 1981; Huxley 1992). Socias (1996) noted the importance of conservation of Mahaleb germplasm in European hereditary banks due to their degradation in natural habitats such as Spain, where six to eight wild species of the genus Prunus were noted, and the most important was Mahaleb. Chehade et al. (2001) surveyed and evaluated the biological diversity of the Prunus species in the Lebanese Bekaa region in terms of its prevalence according to geographical environmental factors. They found the index of biological diversity in Mahaleb varied by 59%, and the most different specifications were between its wild forms, the weight of the fruit, the length of the leaf neck, and the leaf area index.

The wild condition exists in most of the eastern Mediterranean forests associated with Cilician fir (*Abies cilicica*) and Lebanon cedar (*Cedrus libani*), on 2000 m elevation (Mouterde 1970, Barkuda and Audat 1983; Barkuda et al. 2002). Currently, there is growing interest in expanding Mahaleb cultivation in promising agricultural areas due to its low agricultural requirements and endurance of harsh environments. For instance, in Syria there are 5737 hectares of cultivated land containing around 1.3 million trees most of which are not in the fruiting stage.

However, the production of kernels around 25 tons annually ranking Syria in the advanced position (The annual agricultural statistical abstract 2016). In addition to the economic feasibility of cultivating where farmers found an economic benefit from cultivating it because of the demand for it for its nutritional and medical value and for being part of many industries. Its kernel oil contained a high level of polyunsaturated fatty acids especially, α-eleostearic, which is a conjugated fatty acid rarely found in vegetable (Sbihi et al., 2014) and for the future, it may be important for clinical nutrition and the food and pharmaceutical industries (Özçelik et al. 2012). Phenotype differences of Mahaleb were studied in Turkey and Italy as a valuable genetic material for seed breeding programs (Gass 1996); several clones of drought and carbonates tolerance clones were selected for arid calcareous soils (Baumann 1977; Giorgio et al. 1992; Giorgio and Standardi 1993). The Eastern Mediterranean where is characterized by historical degradation as a result of habitat damage due to frequent fires, wood extraction, and overgrazing. In particular, Mahaleb is suffering from tremendous depletion in genetic resources in their origin habitats (Nabulsi 2004). However, Tawaklna et al. (2011) found and studied 22 phenotypes of wild mahaleb in Syria.

This study aims to know the autecology of Mahaleb and to study its landscape ecology in different ecosystems in the middle and northern parts of the eastern facade of the Mediterranean.

Methods

Study area

A comprehensive field survey and a spatial investigation were carried out on the locations where wild or cultivated Mahaleb exist in both the natural forests and some mountain areas where the remnants of the perennial wild trees still grow, in order to study Mahaleb in its natural habitats. As well as, in some sites that are planted and irrigated by local farmers. Information regarding the locations was retrieved from a variety of sources: available documents and literature, official statistics from the National Statistical Agencies, and the local inhabitants (Fig. 1).

Fig. 1. A map of Mahaleb study sites in the middle and northern parts of the eastern facade of the Mediterranean

Field surveys

Survey methodology was adopted according to Maxted (1997), where the location of the Mahaleb in each study area was initially investigated. Homogeneous areas of about $100m^2$ to $400m^2$ were selected as (relevé area) and the following parameters were recorded and studied (Chalabi, 1980; Sankary 1988):

•The geographical coordinates according to the world system (longitude and latitude, World Geographic System WGS 84)

•The altitude above sea level (in meters)

•The size of the site

•Topography and main features of the site

•The slope, aspect, gradient percentage.

•The parent rock and soil parameters

•The abundance of Mahaleb, kind of regeneration, and the current state of trees

• Prevailing vegetation cover and its associated plants.

A numerical scale was used to define the abundance of Mahaleb, based on numbers within the range of 1 to 5 where each number specifies a level that is defined as follows (Braun-Blanquet 1928; 1964; Whittaker 1973; Mueller-Dombois and Ellenberg 1974; Chalabi 1980; Nader 1985):

5: the species covers more than 3/4 of the relevé area (more than 75%).

4: covers from 1/2 to 3/4 the relevé area.

3: covers from 1/4 to 1/2 the relevé area.

2: covers 1/20 to 1/4 the relevé area.

1: numerous individuals, but less than 1/20 of the relevé area, or scattered individuals with a cover of up to 1/20 of the relevé area.

+: [Pronounced plus] few individuals <1%.

Soil describing and sampling was based on procedures of USDA-NRCS (1998). The Munsell Soil Color Charts was used to record the color of the

2.3. Soil sampling and laboratory analyses.

Soil samples were taken from topsoil (depth of 0 to 30 cm) for laboratory analysis, where they were air-dried and then mashed, and then the parts> 2 mm were sifted in the sieve, and then conducted on the parts with a diameter> 2 mm, the following physical and chemical analyses:

The particle-size analysis was performed by the hydrometer method with the application of sodium-hexametaphosphate ($Na_6P_6O_{18}$) as a chemical dispersion agent, Soil Survey Division Staff (1993).

The Walkley-Black method (1934), modified by Nelson and Sommers (1982) was used to determine the soil organic matter.

Electrical Conductivity (EC) was measured in the suspension of H_2O (1:2), Soil Conservation Service (1992).

Soil reaction (pH) was measured in the suspension of H_2O (1:1), Soil Conservation Service (1992).

Total Nitrogen was estimated by (Kjeldahl 1883) and McRae (1988).

Total potassium was estimated by (Jackson 1956).

Available phosphorus was estimated by (Olsen 1954).

Calcium carbonate content was determined by (Balázs et al. 2005).

Climate data

Climatic data were used for all study sites that contain climate stations and for a recording period of at least 30 years. For the sites that do not contain climate stations, data were determined arithmetically based on data from the neighboring climate stations. Complementary assessment of precipitation and temperature was obtained using a guide of Arley (1937) for those regions of the Mediterranean climate, which is estimated to increase rainfall by about 49 mm per 100 m altitude, and a constant of Combier (1933) which is estimated to decreasing of temperature by -0.6°C per 100 m altitude increasing. Hence, defining the following climatic characteristics:

Precipitation Characteristics

Flowing characters were determined: Mean Annual Precipitation, Quarterly precipitation pattern, Seasonal Trend (K), Precipitation Covariance Variance (C.V).

The pluviothermic quotient of Emberger (1955) and Daget (1977) was used to determine the bioclimate and variant of each study site.

$$Q_2 = \frac{2000\overline{P}}{M^2 - m^2}$$

where: Q the pluviothermic quotient, P is the average annual precipitation in mm, M is the mean of the maximal temperature of the hottest month in°C (degree absolute) and m is the mean of the minimal temperature of the coldest month °C (degree absolute).

According to the Q_2 values, five categories of humidity could be distinguished (Table 1).

Table 1 Humidity categories defined according to values of Paluviothermic quotient (Q_2).

As the role of the minimum temperature of species distribution has been pointed out by Larcher (1983) and Woodward (1987). Therefore, (Quézel et al. 1985; Daget et al. 1988; Barbero et al. 1992) have suggested winter variants according to the values of m (Table 2).

Table 2 Winter variants according to the value of m.

The mean thermal values and the thermal continentally index expressing the evaporation intensity for each study site were calculated according to the following equations, (Le Houerou 2004):

$$\boldsymbol{M}=[(M+m)/2]$$

$$K=M-m$$

where: **M** mean thermal values (ºC), M mean maximum temperature for the warmest month of the year (ºC), m mean minimum temperature for the coldest month of the year, *K* thermal continentally index.

Studied sites are ranked by K values within one of the following ranges: *K< 15: Oceanic Insular Zone, K =15-25: Lowland Littoral Zone, K = 25-35: Semi-Continental Zone, K > 35: Continental Zone*

Thermal Characteristics

Including Winter Temperateness Index (WTI) and Winter Index (WI); Sankary (1988) (Table 3).

Aridity Index estimated using the calculation of the degree of continentally (Gorczynski 1922; Abbas 1990):

$$C = \frac{1.3(M - m)}{\sin Q} - 36.3$$

Where: C the degree of continentally (%), M-m The difference between the mean maximum monthly temperature for the warmest month and the mean minimum monthly temperature for the coldest month of the year, Q latitude.

Digital data and statistical analysis

To develop a digital map of Mahaleb distribution, a digital database was established using GIS (Hijmans et al. 2005). The data were analyzed statistically using the Statistical Analyses System (SAS).

Results

The results of the eco-geographic survey confirmed that Mahaleb is present where the EU-Mediterranean climate prevails. Its occurrence was monitored in the middle and northern parts of the eastern facade of the Mediterranean. In six locations where its were observed in wild conditions, and in four sites it was in cultivated conditions. However, it is disappeared completely from some locations, where it was strongly believed to exist. The topographical features of the sites of Mahaleb diffusion varied, as they appeared on steep slopes, between rocks, and in the flat agricultural plains, associated with a variety of plants. The following is a brief description of Mahaleb studied areas.

Relevé code: SD Location: Daher al Jabal Governorate: As-Suwayda Coordination: 32°40'34".3N 36°39'65".5E Elevation: 1555m Topography: Mountainous-Volcanic cones Parent material: Basalt Slope: Strongly sloping, concave liner Aspect: South east Vegetation: *Korschinskii Amygdalus, Cupressus sempervirens, Crataegus azarelus,* *Quercus calliprinos* The relevés status: Rugged and hard to reach Status of Mahaleb: Clustered individuals of varying growth	
Relevé code: RE Location: Assal al-Ward- al Sahrej Governorate: Rif Dimashq Coordination: 33°53'53".8N 36°19'17".0E Elevation: 2019m Topography: Mountainous area Parent material: Calcerous Slope: Steep Aspect: West Vegetation: *Juniperus excels, Poterium spinosum, Inula viscosa Aiton, Rosa damascene, Anabasis articulat, Amygdalus orientalis, Cartaegus azarelus, Berberis vulgaris*	

The relevés status: Degraded due to overgrazing
Status of Mahaleb: Scattered individuals with seedlings

Relevé code: REw
Location: Assal al-Ward- al Washel
Governorate: Rif Dimashq
Coordination: 33°55'03".4N 36°18'44".2E
Elevation: 2140m
Topography: Mountainous area
Parent material: Calcerous
Slope: Moderately steep
Aspect: North west
Vegetation: *Juniperus excelsa, Anabasis lachnantha, Amygdalus orientalis, Cartaegus azarelus*
The relevés status: Degraded due to overgrazing
Status of Mahaleb: Isolated individuals of varying growth

Relevé code: Rg
Location: Serghaya
Governorate: Rif Dimashq
Coordination: 33°47'40".0N 36°08'62".0E
Elevation: 1413m
Topography: Mountainous area
Parent material: Colluvial deposit, Calcareous
Slope: Nearly level
Aspect: N. D
Vegetation: *Prunus avium*
The relevés status: Agriculturally invested

Status of Mahaleb: Planted and irrigated	
Relevé code: Hj Location: Josiah Al-Kharab Governorate: Homs Coordination: 34°23'73".0N 36°34'03".0E Elevation:613 Topography: Undulated hilly land Parent material: Limestone Slope: Nearly level Aspect: N. D Vegetation: *Prunus avium, Juglans regia, Prunus armniaca, Vites vinifera, Amygdalus, Prunus microcarpa* The relevés status: Agriculturally invested Status of Mahaleb: Isolated individuals	
Relevé code: Im Location: Jabal Al-Zawiya-Ma'riblet Governorate: Idleb Coordination: 35°47'97".0N 36°40'51".0E Elevation: 481m Topography: Mountainous area Parent material: Calcareous Slope: Nearly level Aspect: North west Vegetation: *Ficus carica, Olea europaea* The relevés status: Agriculturally invested Status of Mahaleb: Planted	

Relevé code: It
Location: Jabal Al-Zawiya-Kafrlata
Governorate: Idleb
Coordination: 35°48'50".0N 36°36'83".0E
Elevation: 699m
Topography: Mountainous area
Parent material: Calcareous
Slope: Very gentle slope
Aspect: South east
Vegetation: *Olea europaea, Juglans regia, Ficus carica, Prunus avium*
The relevés status: Agricultural investment
Status of Mahaleb: Planted

Relevé code: Lsr7
Location: Slinfah- Cedar Reserve
Governorate: Lattakia
Coordination: 35°34'54".2 N 36°13'11".8E
Elevation: 1402m
Topography: Mountainous area
Parent material: Dolostones
Slope: Very steep
Aspect: South west
Vegetation: *Abies cilicica, Cedrus libani, Juniperus oxycedrus, Quercetum psedudo cerris Quercus infectoria, Quercus calliprinus*
The relevés stauts: Degraded
Status of Mahaleb: Isolated individuals of varying growth

Relevé code: Lse1
Location: Slinfah- Ain El Wdi
Governorate: Lattakia
Coordination: 35°36'04".4N 36°13'50".3E
Elevation: 1299m
Topography: Mountainous area
Parent material: Dolostones
Slope: Very steep
Aspect: North west
Vegetation: *Prunus avium, Juglans regia, Crataegus azarelus, Myrtus communis, Spartium junceum*
The relevés status: Degraded due to woodcutting
Status of Mahaleb: Isolated individuals of varying growth

Relevé code: Ak3
Location: Kafr Janneh
Governorate: Aleppo
Coordination: 36°36'27".4N 36°54'29".4E
Elevation: 403m
Topography: Hilly
Parent material: Clay deposit
Slope: Nearly level
Aspect: North west
Vegetation: *Olea europaea, Prunus avium, Capparis spinose, Spartium junceum*
The relevés status: Degraded due to urban encroachment
Status of Mahaleb: Isolated individuals

Physical and chemical properties of the soil of the studied sites:

Soil textures varied from sandy loam (Lsr7), sandy clay loam (Lse1), clay loamy in both (SD) and (Hj), and clay in the rest of the locations (Table 3).

Table 3 Soil particle size distribution.

The chemical and fertility properties of the soils in which Mahaleb is occurring have varied widely (Table 4).

Table 4 Chemical analysis of study sites soils.

Results of the climatic study of the studied sites:

The results showed that the average prevailing temperature in the sites ranged between 7.78 and 34.8 °C, while the (WTI) ranged between glacial to cold, and the (WI) between glacial winter to a cold winter (Table 5).

Table 5 WTI and WI for the study sites.

The annual rainfall ranging from 257.7 to 1425.1 mm, with (C.V) between 0.223 and 0.37 and standard error is 126.6. The seasonal pattern of precipitation is winter-spring-autumn-summer (Table 6).

Table 6 The character of rainfall of the study sites.

According to the pluviothermic quotient of Emberger, Mahaleb occurs in bioclimatic stages from humid cold to semi-arid fresh with frequent to occasional frost frequency (F.F) (Fig. 2).

Fig. 2. The distribution of study sites on Emberger's climagram.

The indicators of the drought showed that the thermal average of Mahaleb ranges between 12 and 19.

The degree of continentally that can serve as aridity index ranges between 24 and 38.08; i.e. from continental to semi-continental to coastal with a range exceeding 14. Spatial continental values ranged from 49.05 at (REs) to 14. 49 at (Lse1) (Table 7).

Table 7 The mean thermal and continental mean values for each studied site.

Discussion

Prunus mahaleb appears in the middle and northern parts of the eastern facade of the Mediterranean in both wild and cultivated conditions. The wild Mahaleb occurs in its habitat in the form of isolated individuals and fragile structures of populations that were largely believed to have been in clumped or linear populations. Nowadays, its spatial distribution is restricted to small isolated zones in half-open, treeless, or rocky outcrops areas of deciduous forests or rugged areas of barren mountains. The root sprouting seems to be the dominant mode of recruitment that could promote the distribution. However, all sites showed missing age classes that may indicate human infringement or the failure of recruitment in some years. In two rugged sites, Populations with gaps in the age structure episodic and lack of recruitment have been found where it is believed that the presence of these sites in cliffs and outcrop lands secured certain stability from the infringement in the surrounding areas. There is an occurrence of Mahaleb in diverse environments regarding rainfall, average annual temperature, and the average lowest temperature for the coldest month of the year. Where the spatial distribution showed that Mahaleb exists in different environmental and climatic conditions, where trees and seedlings have occurred at a height of 2140 m at the site (Res) and an altitude of 403 meters (Ak3), a difference of 1743 meters. This can be attributed to its possession of genetic capabilities that enable it to adapt to varying environmental conditions in addition to the presence of different genotypes that reflects various environmental conditions (Vivero et al. 2001). Although this occurrence is not widespread, it supports previous studies that confirmed that some countries of western Asia such as Syria, Turkey, Iran, Iraq, and Lebanon are also the original homeland of Mahaleb. Where can be found in wild conditions in the forest and mountainous areas (Mouterde 1970; Chalabi 1980; Nahal et al. 1989; Ghazal 1994; Ghazal Asswad 1998; Chikhali 2000). No individuals of Mahaleb were observed in Orontes plain and in Jisr al-Shughur contrary to what some previous studies indicated (Mouterde 1970; Barkoudeh and Audat 1983). Besides, its presence was very rare in the Anti-Lebanon mountain range and the Qalamoun Mountains, where cherry cultivation abounds in abundance, and this may be due to the use of wild trees as assets for grafting cherries. This illustrates the extent of the genetic erosion to which Mahaleb was exposed by human activities such as changing the agricultural system in its natural habitats, as well as the overgrazing and logging of old trees and seedlings alike.

Soil data indicates that the growth of Mahaleb occurs in soils of various textures, and this is in line with the findings of each of Bean (1981) and Huxley (1992). The degree of soil interaction (pH) appeared different, with a range of 1.64. This indicates the resilience of Mahaleb towards the soil pH, where it was found in soils of different pH, ranging from a slightly acid (SD) to a moderately alkaline (Im), this corresponds to what Bean (1981) and Huxley (1992) indicated that it favors slightly acid soils and suffering from chlorosis in the soil of moderately acid or higher. Soil salinity was low in most locations, while the most prominent variation was in the calcium carbonate that directly affects the mobility of trace elements in the soil, especially iron. Mahaleb has shown some resilience indicators as it tolerates high levels of calcium in the soil, whether in the seedling phase or whole trees. Where the calcium carbonate ratios in the soil of the studied sites ranged between 4.38% at the site (SD) and 42.08% at the site (Ak3) between 4.38% at the site (SD) and 42.08% at the site (Ak3). The percentage of organic matter content in the studied site soil varied. The highest was in the site (Lse1), (REw), and (Lsr7) with values of 4.79%, 4.52%, and 4.42%, respectively, while the lowest was in the site (Ak3) reached 0.57%. This indicates that it is of low nutritional requirement and grows in both fertile and poor soils. Site soil was characterized by a significant total nitrogen content; the maximum was 1.01% in (Lsr7). The content of available phosphorus was rated as good; (Sd) was the heights with (55.1 $mg.kg^{-1}$). As well as, good content of available potash, the maximum was (428.2 $mg.kg^{-1}$) in (Rg). However, the site (Ak3) was poor with available potash (126.6 $mg.kg^{-1}$). Notable, strong, long root systems were observed growing in soils of different depths, even within the joints of the rocks, and this strengthens its role in protecting the soil from water erosion. According to the pluviothermic quotient of Emberger, it can be concluded that Mahaleb is one of the plants that occur in a different bioclimatic stage where the pluviothermic (Q_2) accedes 34. The indicators of the drought showed that the thermal average of Mahaleb ranges between 12 and 19. This suggests that the biological zero of these variates ranges between 10 and 20 °C. The degree of continentally expresses a high ability of (tree and seedling) to withstand environmental, thermal, and water stresses.

The variety of soil properties and diversity of climate parameters where Mahaleb occurs indicates that this geo-environmental diversity may be reflected in the presence of different genotypes or higher taxa such as subspecies or even it may reflect the differences of environmental resilience inside some species themselves.

The only study that was implemented by Tawaklna et al. (2011), where 22 wild phenotypes were identified and described, six of them which are superior in the morphological characterization were selected. Further studies must build on the same study, even though it did not rely on a sound approach to the description of Mahaleb. Rather, it relied on the methodology for the description of cherries approved by the International Plant Genetic Resources Institute (IPGRI) because the description of Mahaleb simply does not exist yet. Moreover, the study did not find possible correlations between phenotypes and eco-geographic conditions.

Conclusion

Mahaleb in the Mediterranean has been present since ancient times where its seeds were still used in nutrition and industry. It is used as a rootstock of cherry trees due to the strength of its roots and its tolerance to drought and the high carbonation in the soil. It can be found in wild and cultivated conditions.

Mahaleb has developed over time a phenomenon of acclimatization towards the surrounding environmental factors, such as terrestrial and climatic environmental stresses. Its smooth, shiny leaves formed a way to reflect sunlight, thereby avoiding its direct thermal effect, on the one hand, and reducing evapotranspiration intensity on the other hand .

The environmental resilience of Mahaleb has created important roles in the eastern Mediterranean forest that can play in progressive succession as medium-sized trees within the climax community and as shrubs in the reactionary succession within the deteriorating forest apogee community .

In cultivated land, there is an increasing interest in the cultivation of Mahaleb in the last decades, as a promising tree in the hilly and mountainous areas as a tree capable of withstanding the harsh environment in addition to its good economic returns, low requirements, and resistance to diseases, so its cultivation has spread steadily. Also, its wide environmental range indicates the presence of many phenotypes suited for promising agricultural areas. To achieve this, detailed studies should be conducted to determine the critical (biotic and abiotic) stress boundaries of

Mahaleb trees in their natural habitats to elect acclimatized clones in each environmental region.

It is also necessary to predict new potential areas for growth Mahaleb in the eastern Mediterranean to increase production either by introducing its cultivation in unconventional areas or by enhancing its productivity in the areas currently cultivated, which appears to be an important issue soon.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

All data generated or analysed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Tawaklna originally formulated the idea, Hag Husein developed the methodology, Hag Husein and Tawaklna conducted fieldwork, Bao Pham performed statistical analyses, and Bäumler and Bao Pham and Hag Husein wrote the manuscript.

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Competing interests

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List of abbreviations

Ak3	Kafr Janneh site

C.V	Covariance Variance
EC	Electrical Conductivity
F.F	frost frequency
Hj	Josiah Al-Kharab site
Im	Jabal Al-Zawiya- Ma'riblet site
It	Jabal Al-Zawiya- Kafrlata site
Lse1	Slinfah- Ain El Wdi site
Lsr7	Slinfah- Cedar Reserve site
pH	Soil reaction
Q_2	Paluviothermic quotient
RE	Assal al-Ward- al Sahrej site
REw	Assal al-Ward- al Washel site
Rg	Serghaya site
SAS	Statistical Analyses System
SD	Daher al Jabal site
WGS 84	World Geographic System
WI	Winter Index
WTI	Winter Temperateness Index

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Figures

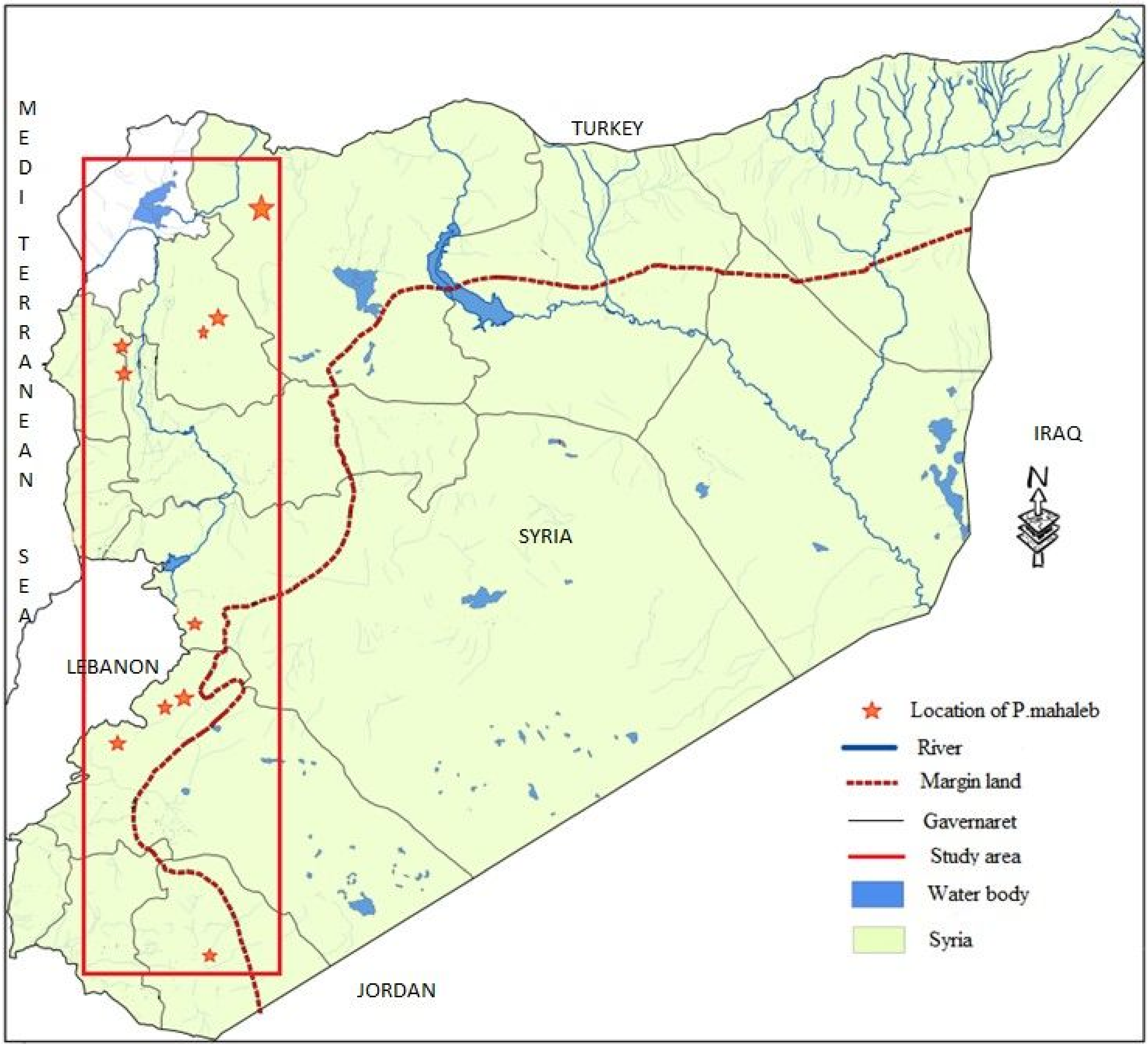

Figure 1

A map of Mahaleb study sites in the middle and northern parts of the eastern facade of the Mediterranean Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

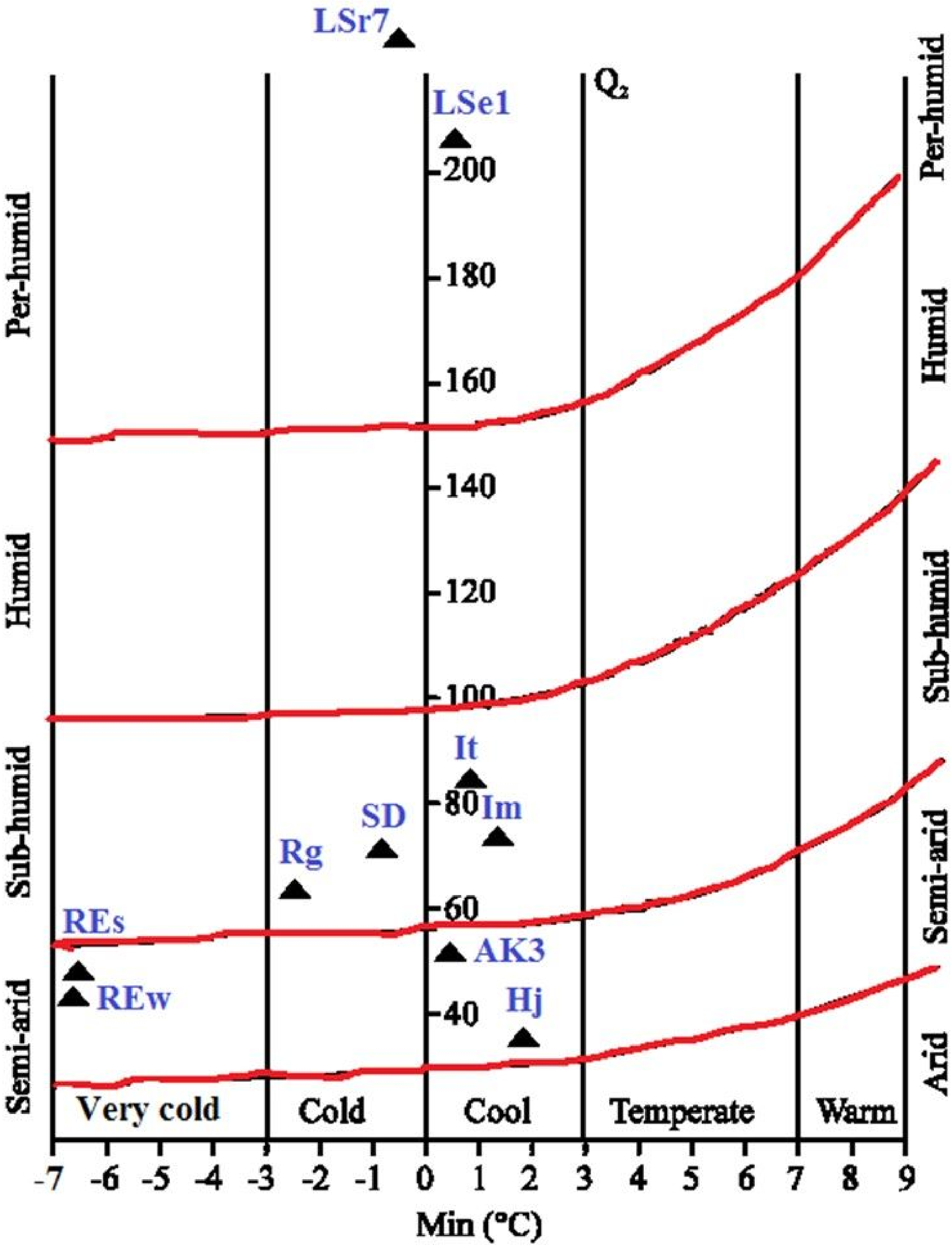

Figure 2

The distribution of study sites on Emberger's climagram.

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