

New data on the ecological distribution of *Euphorbia resinifera* O.Berg in the Beni Mellal-Khenifra region

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Abstract. *Euphorbia resinifera* O. Berg, also called Euphorbusresin, is a species belonging to the Euphorbiaceae family. It is endemic to the Beni Mellal Khenifra region and extends discontinuously between El Ksiba and Demnate. Currently, this plant is known as a meliferous species and its product is considered as a terroir product with a Protected Geographical Indication (PGI). However, few studies have conducted on its ecology and particularly its mapping in relation to the environmental conditions where it thrives. That's why in this study, we tried to establish, for the first time in the region of Beni Mellal, a distribution mapping of *E. resinifera* according to the ecological needs of the plant, the exploration of high-resolution satellite imagery and on the field by observing a representative sample of the study area. Results showed that it spread from Demnate to Elksiba in the Atlas piedmont area but appears as scattered individuals from Demnate to AitOurir due to a complexity of factors mainly related to the soil characteristics, paleogeography and the climate exacerbated by the negative results of anthropogenic impacts. It extends also into the central high Atlas valley as small isolated units which reach 1900 m of altitude. This could explain why other ecological requirements should be considered in terms of the distribution of this endemic species in the context of climate change.

Introduction

Climate change is becoming the main driver of environmental change in the Mediterranean region [1]. In this region, multiple paleo-geographic events and contrasting climatic cycles have led to the emergence of an unusually high biodiversity [2, 3]. The Mediterranean climate of Morocco has become a hotbed of climatic hazards which can lead to successive periods of drought and the aridity of a large part of its territory, which can create favorable conditions for the development and domination of different plant species and climax. Among these species, *Euphorbia resinifera*, O. Berg, also called *Tithymalus resiniferus* (O. Berg H. Karst) or Euphorbus resin which belongs to the Euphorbiaceae family, is an endemic species of Morocco and considered as a plant well adapted to drought. In the Atlas region of Beni Mellal, it extends from Elksiba to Demnate. The oldest illustration of a succulent Euphorbia dates back almost 1500 years, it was identified and proposed by Lawant and Winthagen [4] as *Euphorbia resinifera* Berg from north-west Morocco. Currently, this plant is best known for its use in the melliferous field, since the euphorbic honey derived from this plant is considered a local product with Protected

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Geographical Indication (PGI) in the Tadmra-Azilal region[5]. Despite the botanical and morphological differences, this species has long been confused with *E. Officinarum* L. *sspechinus* present in the sub-region south of Morocco. Recently, molecular tools have revealed that they are two different species of euphorbia [6].

In Morocco, *E. resinifera* colonize all the sunny slopes in areas where it is encountered [7]. It grows mainly in the rocky and arid rocks of the low limestone mountains between 600 to 1 500 m [8]. In 1937[9], Gattefossé and Vindt have estimated its area to about 130 000 hectares. But, in 1966 the Moroccan Ministry of Agriculture and Agricultural Reform limited the geographical area of this plant to the following zones: Haouz, Middle Atlas, Umm-er-Rbia, Central High Atlas (M'Goun) and JbelLkest. The area in the province of Beni-Mellal is estimated to 8 215 ha [5]. Until now, the figures put forwards about *E. resinifera*'s area question us about the actual extent of the species in its geographical range.

From a phytocoenological point of view, *E. Resinifera* is considered as a thermo-mediterranean species, included in the *Acacia gummifera* series and the *E. resinifera* sub-series corresponding to *Rubio longifoliae-Euphorbictumresiniferae* [10]. But when it is considered as a secondary essence, it is found in the *Tetraclino-Euphorbietumresiniferae* association characterized by a temperate semi-arid climate growing on the dolomites and limestone where it finds on this substrate the solid support, the heat and the dryness which it needs [11]. It is located in the regions of Bezou, Beni Mellal and Demnate between 900 and 1 100 m [10]. According to Benabid[12], the species is part of the Macaronesian floristic procession that characterizes the southwestern coast of Morocco and the Canary Islands. The species grows in the marginal northeast area of these Macaronesian plantdistributions on the rocky foothills of the Atlas of Beni Mellal and Demnat. Bioclimatic atmospheres can be semi-arid and temperate sub-humid, in the sub-Mediterranean and thermo-Mediterranean vegetation, between sea level and 800 m. The association of plants described by Fennane [11] is part of the vegetation subset of *E. resinifera* which is included in the *Acacia gummifera* vegetation series.

Currently, field observations show that *E. resinifera* is mainly observed in the Beni Mellal-Khenifra region and there is a lack of data related to its redistribution, particularly its spatiotemporal evolution. It is in this perspective that this work was approached and focused on its distribution area with the aim to:

- Determine the range of *E. resinifera* in its native region in the Atlas of Beni Mellal and the Central High Atlas in Morocco through the use of remote sensing and fieldobservation;
- Identify some ecological traits and characteristics that drivethe distribution of this species;
- Define a reference state GIS based approach for cartography and spatiotemporal analysis in the scope of *E. resiniferastands* preservation actions.

Material and methods

To address the objectives of this study, the designed methodology is divided into three major phases:

1. Delimitation of the potential area of *E. resinifera*

For this purpose, the visual interpretation of satellite imageries with very high spatial resolution was used. These are single-spectral satellite scene covering the whole study

area. All the images were acquired from the free Google Earth platform and are displayed in real colors and visually interpreted in a GIS environment. Several satellite images were used, with suitable dates and geographical areas, to cover the entire study area and benefit from maximum precision.

Indeed, the digitalization of the *E. resinifera* range was based on the shape, texture and structure of the euphorbia patches which are, in most cases, clearly visible to the interpreter's eye.

2. Validation by field observations

After finalizing the extent of *E. resinifera* distribution, it would have been appropriate to validate this work by careful field verification. As a result, several control points were randomly selected to verify both the presence of the species and to inquire about any relevant data regarding the descriptors of the euphorbia developmental environment. The table 1 and figure 1 below summarize this phase:

Table 1: Coordinates and ecological characteristics of the studied sites

| Check point n° | Locality | Latitude(dd)* | Longitude(dd) | Altitude(m) | Density of <i>Euphorbus resin</i> |
|----------------|----------------------------|---------------|---------------|-------------|-----------------------------------|
| 1 | Cemetery of Beni Mellal | 32,3460211 | -6,31589088 | 604 | Sparce density |
| 2 | - | 32,5341135 | -6,14929764 | 613 | Clear density |
| 3 | - | 32,5435261 | -6,13884432 | 660 | Dense |
| 4 | Cemetery of IghremN'Laalam | 32,564955 | -6,129555 | 627 | Absent |
| 5 | - | 32,5860822 | -6,032355 | 873 | Sparce density |
| 6 | Tighboula | 32,5860822 | -6,032355 | 785 | Absent |
| 7 | - | 32,5827137 | -5,99817105 | 1068 | Absent |
| 8 | El Ksiba | 32,5718496 | -6,03810582 | 1041 | Sparce density |
| 9 | El Ksiba | 32,5660948 | -6,066856 | 1041 | Sparce density |
| 10 | - | 32,5511 | -6,0856 | 944 | Sparce density |
| 11 | Ikhourba | 32,50054 | -6,153433 | 662 | Dense |
| 12 | Tagzirat | 32,4195655 | -6,2203465 | 690 | Clear density |
| 13 | Foumelanser | 32,36939 | -6,25465792 | 746 | Medium density |
| 14 | Sidi brahim | 31,6442 | -7,4599 | 700 | Absent |
| 15 | Tazart | 31,64961 | -7,44381 | 732 | Absent |
| 16 | Aitkaaboch | 31,726 | -7,0541 | 1042 | Sparce density |
| 17 | 5 KmSouth of Demnate | 31,75535 | -6,99303 | 1067 | Clear density |
| 18 | Demnate | 31,75962 | -7,0067 | 937 | Dense |
| 19 | Marrakech-Azilal Road | 31,8819 | -6,90124 | 900 | Clear density |
| 20 | Ouzoud | 31,9449 | -6,7641 | 1041 | Sparce density |
| 21 | KsarManar | 32,021319 | -6,470691 | 1450 | Medium density |
| 22 | Oued Ahanssal | 32,021793 | -6,456787 | 1430 | Dense |
| 23 | AitMhamed | 31,87962 | -6,456148 | 1700 | Absent |
| 24 | AitMazigh | 32,082366 | -6,335851 | 1260 | Absent |
| 25 | - | 32,090846 | -6,304826 | 1600 | Clear density |
| 26 | - | 32,06846 | -6,266642 | 1700 | Absent |
| 27 | Tabarouchte | 32,12474 | -6,197198 | 1360 | Clear density |
| 28 | Tillouguitecentre | 32,033247 | -6,205586 | 1256 | Medium density |
| 29 | TillouguiteZt-Ahansal road | 31,979669 | -6,09110244 | 1850 | Sparce density |
| 30 | TillouguiteZtAhansal road | 31,979471 | -6,08375702 | 1920 | Sparce density |

*Geographical coordinates expressed in WGS84 system.

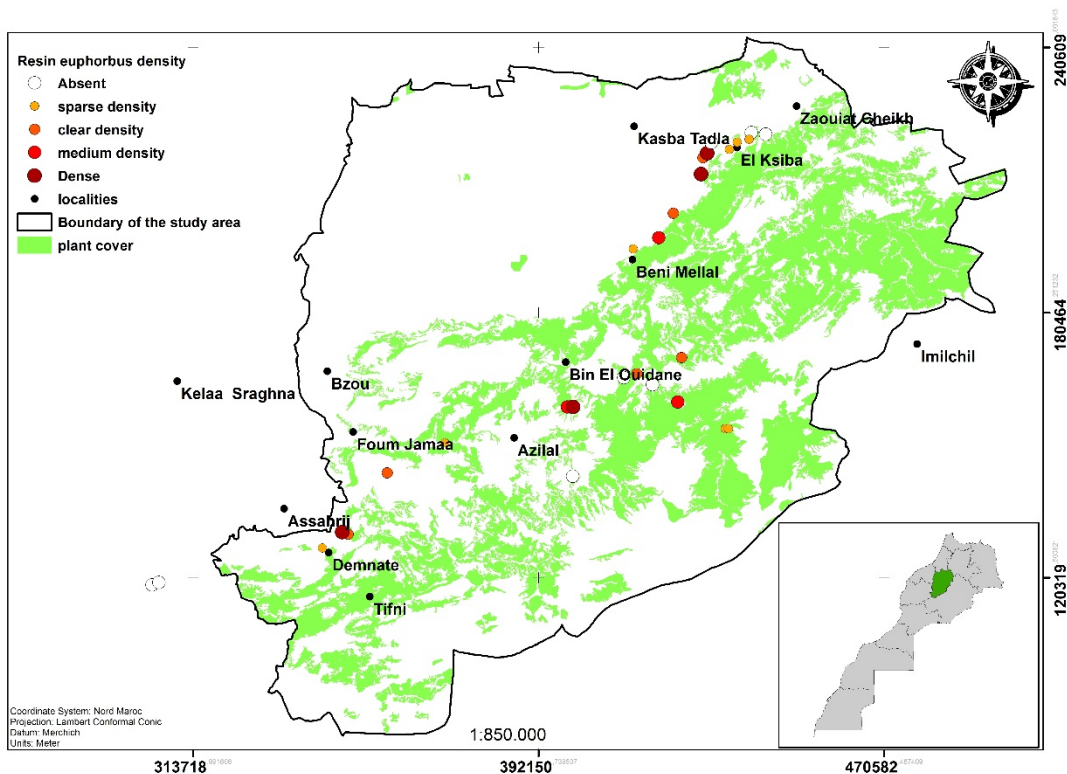


Fig. 1. Field positions and status of sampled control points of *E. resinifera*.

3. Spatial analysis by superposition

Overlapping this limit to the range of edaphic and morpho-climatic factors involved in the distribution area of the studied species. In this case the spatial analysis was based on the bioclimatic range (regarding Emberger's map for Morocco in 1955) [13], elevation, slope exposures and substratum (geology).

Results

1. Geographic range

The results of the image-interpretation validated with an accuracy of 73.33% and readjusted to refine the limit of the geographical area of the *Euphorbus resinare* presented in the

following distribution map (Figure 2):

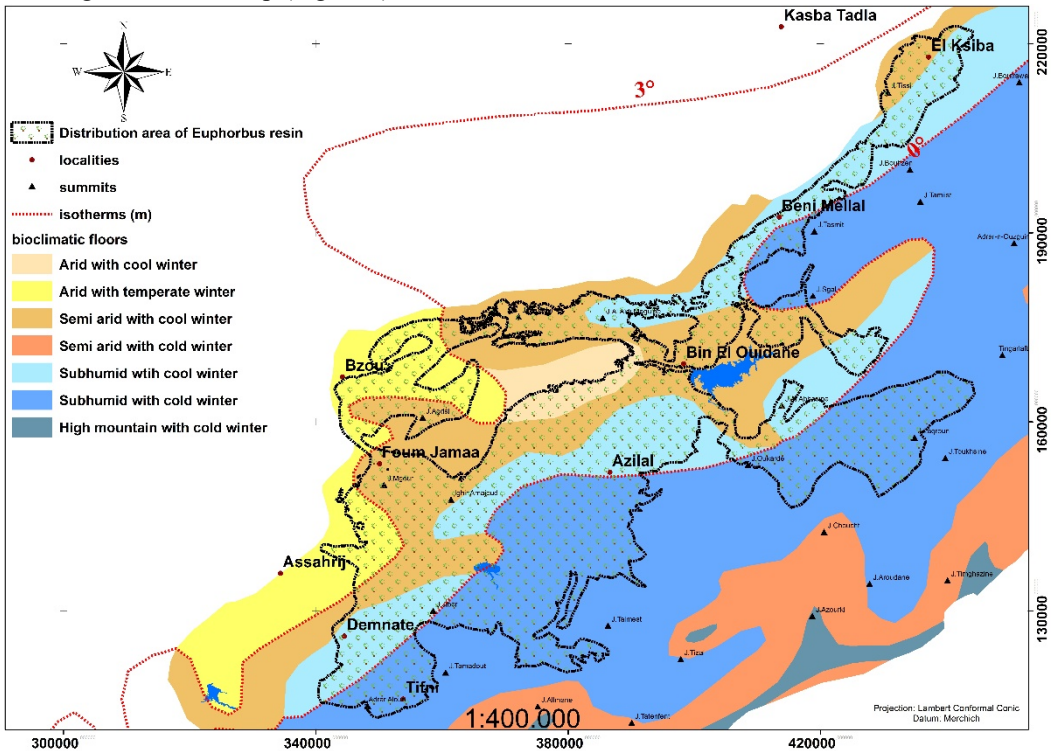


Fig. 2. Distribution of Euphorbus resin in the Beni Mellal-Khenifra region.

According to the map, the geographic area of the euphorbia extends on an area of 316 500 ha, from Demnate (central high Atlas) in the southwest to the Elksiba zone (middle Atlas) in the north-east, with infiltrations in the center of the high Atlas following the continental gradient where the euphorbia grows under specific microclimatic conditions: rocky soils, hot exposures and a clear to patchy density of the tree cover. Most of this area is located at the level of the north Atlassian piedmont. From a bioclimatic point of view, the area of euphorbia is found in arid to sub-humid bioclimates but with temperate, cool and exceptionally cold variants.

2. Hypsometry range

If several research studies have shown that Euphorbus resin plant associations elevation spread from 680m to 1 100m. It's interesting to note, from this study, that the upper part of its area reaches 1 200 m ranging thus between 600-1 200 (figure 3). Also, this study newly reports the presence of this species was observed at altitudes above 1 900m. This area extension indicates a possible migration to high altitudes as a result of climate change leading to an increase in temperatures (shifting of the 0°C isotherm to the east).

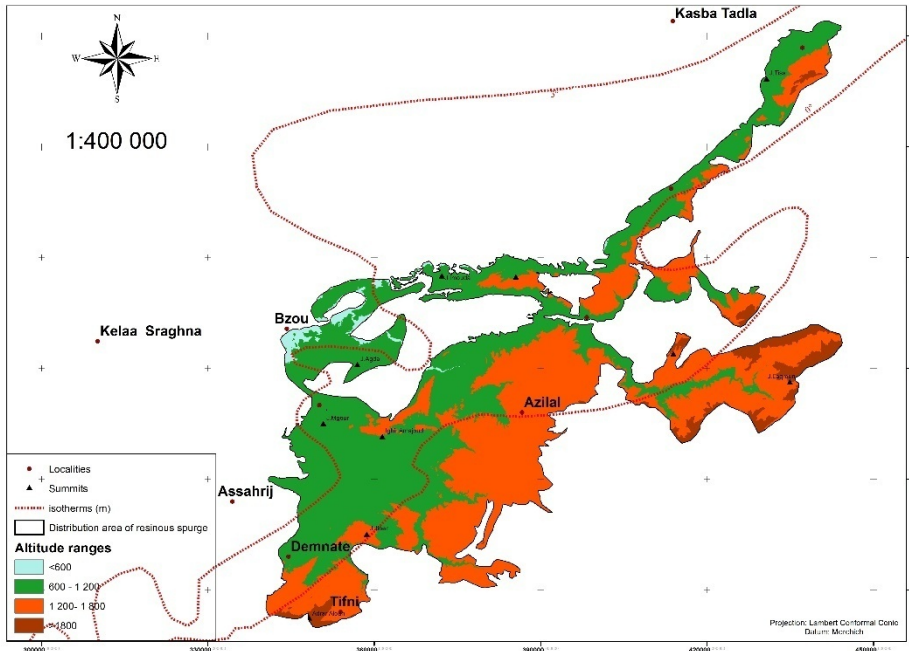


Fig. 3. Hypsometry and isotherms for the Euphorbus resin distribution

3. Range geology

The geological map below (figure 4) illustrates a clear location showing that the majority of the resin Spurge geographical area is dominated by Lias geological formations characterized by limestone, dolomitic and dolomite-limestone substratum. This finding corroborate that the spurge formations develop on calcareous substrates, dolomite, rocky soils and cracked slabs, which shows the rupicolous character of the species.

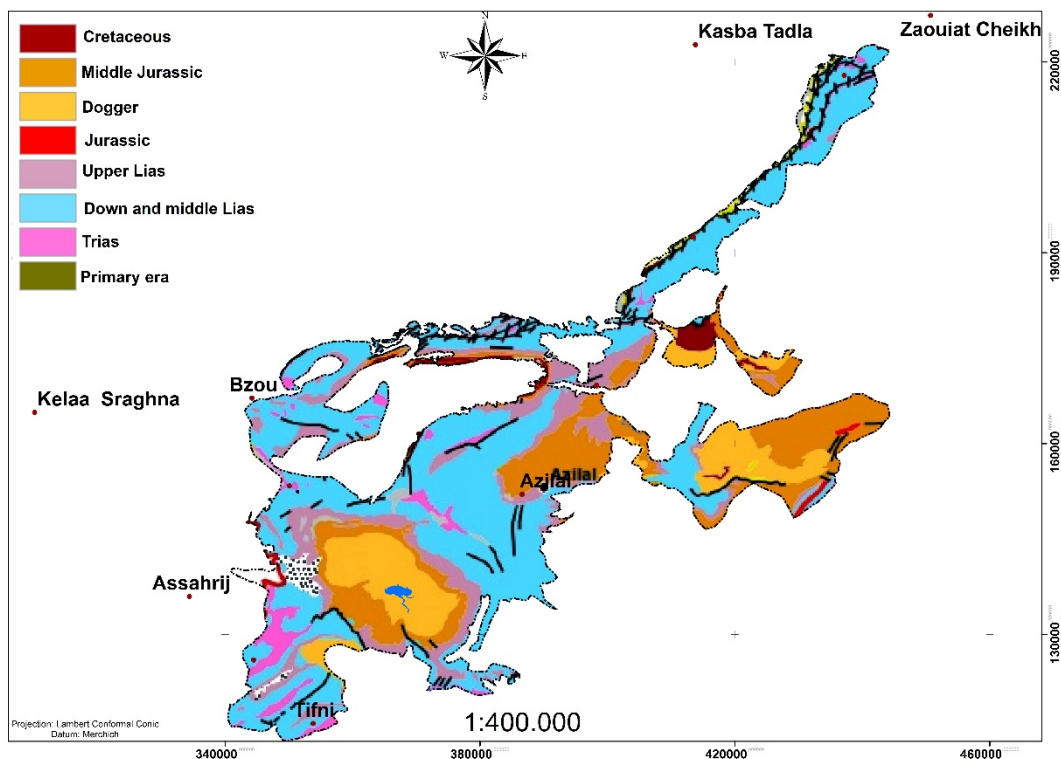


Fig. 4. Geological range of Euphorbus resin in the Beni Mellal-Khenifra region.

Discussion

This study aims to complete the gaps in the geographical distribution of an endemic and economically important plant in Morocco, particularly in the region of Beni Mellal-khenifra. Field surveys revealed that *E. resinifera* is mainly concentrated, from the northeast of El Ksiba (Middle Atlas) to the southwest of Demnate (High Central Atlas) with infiltrations in the center of the High Atlas following the continental gradient, where the spurge thrives on rocky soils with warm exposures and a clear to sparse density of the canopy cover. This result is in agreement with that of Benabid and Fennane [10], where they noticed that the bulk of this area is located at the level of the North Atlasian piedmont. From a bioclimatic point of view, it seems that this species prefers arid, semi-arid and locally subhumid atmospheres with temperate, cool and exceptionally cold variants. This justifies its presence on the altitudinal range from 600 to 1 200m as indicated by Benabid [12] and designated as a part of the large Mediterranean-Saharan regional transition zone [14].

However, it's surprising that the species was also found at altitudes higher than 1 900m, suggesting that this species existed in this altitudinal range before. Furthermore, previous studies have never mentioned its presence at similar altitudes [9, 10]. Thus, future research on the ecophysiological traits of the species is necessary to better document this unusual behavior. Another explanation can be attributed to an eventual migration of this species to high altitudes under the effect of climate change leading to an increase in temperatures (decline of the 0°C isotherm to the east). As it was described by White [14], working on Africa's vegetation with a global analysis, the three succulent shrubby species of Euphorbia are confined to the arid 'étage' and the drier, low-lying parts of the semi-arid 'étage', with, in the case of two species (*E. Officinarum* and *E. echinus*), a considerable southwards

extension into the Atlantic Coastal Saharainfluenced by marine currents. They reach their maximum development at the western end of the Mediterranean-Sahara transition zone. *E. resinifera*, meanwhile, occurs in the north-east and south-east exhibitions which are sunny with less oceanic influences. The presence of *E. resinifera* at the altitude up to 1 900m suggests the possibility of a new phytoecological association of *E. resinifera* other than what has been proposed by several researchers [10, 11, 15]. However, caution should be exercised in the analysis, especially in plant and ecological terms, as Mediterranean vegetation is dominated by two main characteristics, namely heterogeneity and vulnerability [16].

The overlay of the euphorbia delimitation map with the geological map of the area showed that it is a rupicolous species. Indeed, most of the geographical area of this resiniferous species is dominated by geological formations of the Lias characterized by a calcareous, dolomitic and dolomite-calcareous substratum. This chain that dates from the Lias is probably different from those of the High Atlas and the Middle Atlas, maybe it is indigenous, while the other chains are allochthonous. In these formations, *E. resinifera* finds on this substrate the solid support, cracked slabs, heat and drought that are indispensable to its growth [11]. It is now clear that the three species of Euphorbia, *E. resinifera*, *E. beaumierana* and *E. echinus* even they are cactoid shrubs with thick, succulent, ridged, spinous stems forming dense clumps which normally grow 0.6-1 m tall, but in range they replace each other geographically [14]. Indeed, there was likely an adaptive strategy in Euphorbia that enabled the occupation of increased arid niche space accompanying Miocene expansion of arid ecosystems. These opportunities evidently facilitated recent, replicated bursts of diversification in Euphorbia [17].

In this study, the question was raised regarding the scatter of this plant in AitOurir and Tizin'Test region, where its presence was reported by Gattefossé and vindt[9] and Boulli [18]. The probable causes of this dispersion is a result of interaction between different factors, notably: the biological constraints generated by an inability to regenerate by natural seedlings; climate changes that have significantly altered the original climate conditions (original paleoclimate) for the regeneration and prosperity of the species and, finally, because of the human activities that, through its impacts and management choices, determine the dynamics of the ecosystems and the magnitude of the phenomena of rarefaction or extinction of the species [19]. In our case, the stands of *E. resinifera* are exposed to the exploitation of sand quarries and rock blocks found mainly in the limestone zone, as well as the conversion of the land into cereals and vegetable crops. All these observations challenge us to rethink the future of this plant considered as plants of multiple uses. Even to stabilize its natural balance, especially its annual floral cycle prerequisite for the survival of bee communities in the region.

Conclusion

This study allowed us to establish for the first time in Morocco a map of the regional distribution of *E. resinifera*, an important species with a high socio-economic and environmental interest. Field surveys show that it concentrates mainly, from the El Ksiba area in the north-east (Middle Atlas) to the south-west of Demnate (High Central Atlas) with infiltrations in the center of the High Atlas following the continental gradient, where it thrives on rocky soils with sunny and warm exposures and a clear to sparse density of canopy cover. Contrary to what has been observed by several researchers, this species was encountered at altitudes exceeding 1 900m. This suggests a possible migration to high altitudes under the effect of climate change leading to an increase in temperatures and also, the possibility of a new phytoecological association of *E. resinifera* other than what has been proposed by several authors. Nevertheless, its dispersion in some areas is a complex

phenomenon subject to soil, paleogeography and climate factors exacerbated by intense anthropogenic action. Efforts must be made and undertaken to reflect on the future of this emblematic species.

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