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Vegetative and efflorescence characterization of carob tree (*Ceratonia siliqua* L.) from the Province of Sefrou, the Middle Atlas of Morocco

N. Seghir[1], E. Harki[2], A. Dahchour[3], N. Gharnit[4], A. Ennabili[1,5]

[1]*LAMEC, Faculty of Sciences, Sidi Mohamed Ben Abdellah University, Fez 30 000 Morocco*

[2]*Department of Biology, Faculty of Sciences and Technologies, Sidi Mohamed Ben Abdellah University, Fez 30 000 Morocco*

[3]*Department of Biology, Faculty of Sciences, Sidi Mohamed Ben Abdellah University, Fez 30 000 Morocco*

[4]*DPMY, Regional Academy of Education and Training, Fez 30 000 Morocco*

[5] *Process Engineering Department, Higher School of Technology, Sidi Mohamed Ben Abdellah University, Fez 30 000 Morocco*

Abstract

The present study used vegetative and floral characteristics to investigate three Moroccan carob populations from different sites of Sefrou province (Middle Atlas, Morocco). The presence of basal rejections in the carob tree indicates that the tree is not regularly pruned by farmers. The average circumference of these rejections is greater at Sekoura M Daz where conditions are more beneficial as shown in leaf characteristics (14.5 cm long, 10.9 cm wide, 7 leaflets and 4.12 cm long petiole), by comparison to Kandar Sidi Khiar. The leaf length and width, and petiole length are most discriminatory. However, the variation of these parameters would then be largely genotypically explained and secondly would be in relation to the provenance. The sex ratio is greater than one, showing that grafting both male and female trees in male and low carob bean-yield is absent. The percentage of developed fruit varies from 17.1 to 21.8%. In addition, place conditions would not explain the highly significant differences in floral and fruiting quantitative parameters studied.

Keywords: Vegetative characterisation; Efflorescence; Carob tree; *Ceratonia siliqua*; Sefrou; Morocco.

Introduction

The carob tree (*Ceratonia siliqua* L., *Fabaceae*) has an increasingly socio-economic and ecological interest in the world (Tous *et al.*, 1996; Battle & Tous, 1997). Originally from the Middle East and the Southwestern Asia, its distribution currently covers the five continents, particularly under the Mediterranean climate (Northern Africa, Middle East, Southern Europe, Canary Islands and more recently in Australia, Southern Africa, the USA, India and Southern America) (Tous *et al.*, 1996; Battle & Tous, 1997; Yousif & Alghzawi, 2000).

Several morphometric studies of tree, leave, fruit and/or seed have been led in carob tree from the principal Mediterranean productive areas to characterise the carob cultivars and/or intra-specific categories (Coit, 1967; Orphanos & Papaconstantinou, 1969; Casanova *et al.*, 1987; Albanell *et al.*, 1988, 1996; Caja *et al.*, 1988; Crescimano *et al.*, 1988; Ouchkif, 1988; Russo & Polignano, 1996; Gharnit *et al.*, 2001, 2003, 2004, 2005, 2006a, 2006b, 2010; Gharnit, 2003; Barracosa & Graça, 2006; Naghmouchi *et al.*, 2009; Sidina *et al.*, 2009; El Batal *et al.*, 2011; El Kahkahi *et al.*, 2014; Hasib & El Batal, 2014). More recent genetic, chemical, biological and *in vitro* culture studies are also established in

CONTACT A. Dahchour ✉ abdeldahchour@yahoo.com 🖃 Department of Biology, Faculty of Sciences, Sidi Mohamed Ben Abdellah University, Route d'Imouzzer, P BOX 2626, 30 000 Fez, Morocco

this specie (Hsina & El Mtili, 2009; Ben Hsouna *et al.*, 2011; El Hajaji *et al.*, 2011; Akkaya & Yilmaz, 2012; Ibrahim *et al.*, 2012; Colak *et al.*, 2013; Benchikh *et al.*, 2014; La Malfa *et al.*, 2014; Oziyci *et al.*, 2014; Mulet *et al.*, 2015).

In Morocco, the carob tree is considered as a peri-forest species having high socio-economic and ecological interests (Battle & Tous, 1997; Gharnit *et al.*, 2001). With its ability to develop different strategies for adapting to water stress, the carob tree grows favourably in arid and semi-arid areas (Morton, 1987; Lo Gullo & Salleo, 1988). Its area is estimated at 30 000 ha (natural and artificial plantations) (Ait Chitt *et al.*, 2007). The carob culture experiencing a resurgence of interest in recent years due to its many industrial applications and its distinguished profitability compared to other fruit species and cereals in non-irrigated land (or Bour) (ORMVAT, 2005).

Carob tree is also recommended for reforestation of degraded areas, threatened by desertification, and disadvantaged rural areas (locust bean and beekeeping), ornamentation (planting alleys and urban green-spaces) and wind breeze (e.g. (Gharnit *et al.*, 2003; Vekiari *et al.*, 2011).

Although studies have interested the carob tree for several provinces of Morocco, to date, carob from the province of Sefrou, which is essentially spontaneous orchards, was never reported or investigated. To highlight eventual intra-specific variation, this work aims to characterise carob tree from the Sefrou province (Middle Atlas of Morocco) using vegetative and floral parameters.

Materials and methods

Study area

Sefrou Province (Middle Atlas of Morocco) is geographically located between the Saïs plain and the Northern foothills of the Middle Atlas. It covers an area of 4,009 km^2, i.e. 19.7 % of the area of the Fès-Boulemane Region (HCP/RGPH, 2004). The area of arable land is estimated at 95,000 ha, of which 15,000 ha are irrigated. The forest occupies nearly 140,000 ha. The substrate of this area is dark calcareous with diversity in its constitution (granite and/or red sandy-granite in the Atlas Mountains (CRFB/MHUPV, 2013).

This Region is characterised by a continental climate with cold winters and dry and hot summer in the Northern part, wet and cold in the mountainous areas of central and semi-desert in the highlands near the Southern Province of Boulemane. The average minimum temperature of the coldest month is about 8.9°C, while the average maximum temperature of the warmest month is 33.7°C. The temperature can exceed 40°C especially during the summer period and when the “Chergui” winds dominate. Moreover, the average annual rainfall is 648 mm. The snow appears from altitudes of 1600 m (CRFB/MHUPV, 2013).

The Sefrou Province shelters a variety of species in its forest heritage, thanks to the diversity of ecological conditions that characterise its territory: holm oak (*Quercus ilex* L.), cedar [*Cedrus atlantica* (Endl.) Carrière], arborvitae [*Tetraclinis articulata* (Vahl) Mast.] and juniper (*Juniperus oxycedrus* L.). The distribution of these species is a function of altitude: *Salsolaceae* in the lower altitudes, alfa and rosemary from 1,000 to 2,000 m of altitude, and Aleppo pine, cedar, red cedar and juniper cade in the higher altitudes (CRFB/MHUPV, 2013).

The Sefrou Province houses a population of 259,577 inhabitants, with 56% of rural population and a density of 67 inhab./Km^2 (RGPH, 2004). Its economy is based on livestock and orchards. The main fruit trees cultivated and/or exploited are olive, apple, plum, cherry, walnut, almond and carob tree (DRA, 2010).

Within the study area, the spontaneous carob irregularly covers fruit orchards. According to a survey carried out

in 2010, three sites in the Province of Sefrou, where the carob tree grows in large populations, have been identified: Skoura M Daz, Zair Sid Lahcen and Kandar Sidi Khiar. Their surface areas are estimated at 70, 150 and 95 ha respectively.

Sampling locations

In 2010, three stations were selected from others to carry out systematic sampling of the carob tree at the Province of Sefrou, Fès-Boulmane Region:

1. Centre Sekoura - M Daz, with orchards based on carob and olive terraces.

2. Oued Guigou Sekoura - M Daz proximal to the Centre Sekoura - M Daz, with orchards abandoned made of carob and olive, and crossed by irrigation canals.

3. Kandar Sidi Khiar, corresponding to a degraded Ceratonaie (development of *Urginia maritima*, *Arisarum vulgare*, *Thymus* spp. , *Salvia* spp., *Asphodelus* spp., grazing) (Figure 1; Table 1).

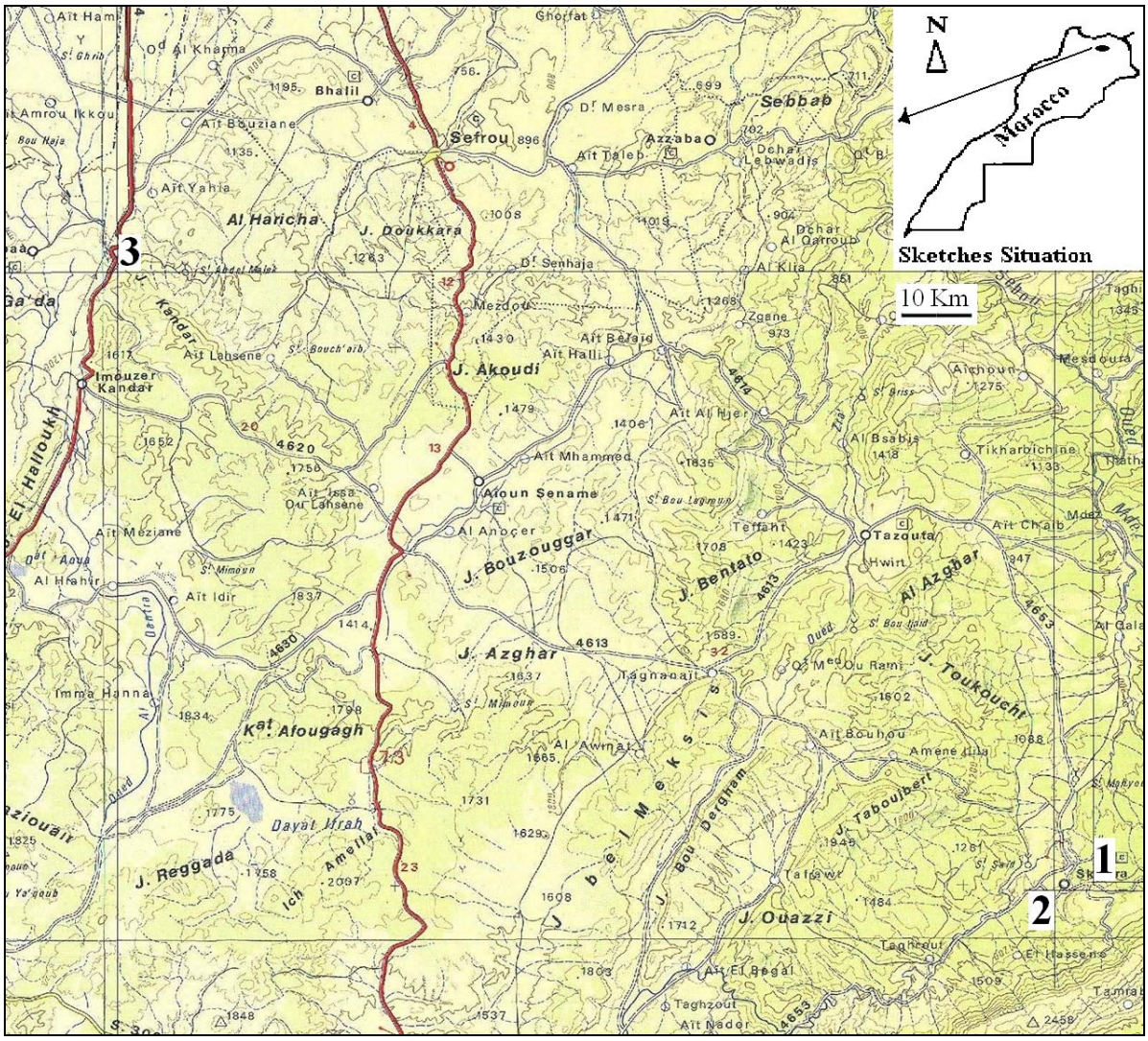

Figure 1. Situation of the studied locations**. Caption**: 1, Centre Sekoura - M Daz; 2, Oued Guigou Sekoura - M Daz; 3, Kandar Sidi Khiar. **Modified Source**: Topographical map of Morocco, Meknes, 1/250 000.

Methods

The carob tree is a spontaneous species in the forest area and peripheral forest as isolated trees and / or semi-groupings, as it is domesticated and cultivated in private domain. This study focused on all trees of the three identified semi-groupings following field surveys. For each selected station, a series of carob trees has been identified (14-16 trees per

locality), and samplings of 30 leaves, and 30 of inflorescences/infrutescences per tree were systematically carried out in accordance with previous studies (Gharnit, 2003; Gharnit *et al.*, 2004, 2005, 2010).

A global description of the tree has interested mainly the number of rejections and their average circumference (20). For the leaf, a number of parameters were followed namely the length (L) and width (W), the ratio "L/W", the number of leaflets, the petiole length, the length (L1) and the width (Lw) of leaflets, and the report "Ll/Lw" (Gharnit *et al.*, 2005).

Table 1. Sampling locations characteristics (2010).

Locations	Geographical coordinates	Altitude (m)	Slope (%)	Observations
Centre Sekoura – M Daz	04°32'48.9804" W 33°31'34.6872" N	1013	10	- Western exposure, - Limestone and conglomerate substrate.
Oued Guigou Sekoura – M Daz	04°33'39.654" W 33°31'15.4956" N	991	60-70	- Variable exposure, - Soil developed and sandstone substrate.
Kandar Sidi Khiar	04°59'37.593" W 33°47'16.455" N	989	40	- Variable exposure, - Limestone substrate.

During flowering/fruiting, the sex ratio, the length of the inflorescence and the numbers of flowers, aborted flowers, aborted fruits and fruits developed by inflorescence were followed (Gharnit *et al.*, 2004, 2010).

All data were processed using the statistics 5.0 software (Statsoft Inc., 1995). Analysis of variance was conducted by (ANOVA 95%) to a single criterion (each parameter selected for this study as a variable) to compare, first, the three stations (inter-locations variation) retaining 14 trees per station (observations of the parameter considered), and the other, the trees of each station (intra-location variation).

Results and Discussion

Botanical Port

Tree height varies approximately 4-18 m for locations surveyed. Rejections of the tree are numerous: 1-24 tree rejections in Kandar Sidi Khiar and 1-27 tree rejections in Sekoura M Daz (Figure 2), showing that the carob tree is not regularly pruned by farmers. The average circumference of rejections is greater in trees from Sekoura Daz M (Figure 2), where the carob tree is apparently more favoured (dominance of crops, irrigated areas, more developed soils) than the carob tree from Kandar Sidi Khiar.

Except exploitation of the carob tree (grazing, lopping), culture (application of manure or fertilizer) and maintenance (coppicing, pruning) are almost absent in the areas surveyed, when compared to other studies (Gharnit *et al.*, 2001, 2006a; Talhouk *et al.*, 2005). Moreover, the shrubby forms with multiple rejections are confined to certain among other unfavourable habitats or due to lack of maintenance (Gharnit, 2003).

Leaves

By comparing the parameters in pairs for three locations, the length and width leaf and petiole length are more discriminating. The number of leaflets per leaf distinguishes the two stations Sekoura M Daz, and Kandar Sidi Khiar successively. While the length/width ratio does not distinguish between the locations surveyed (Table 2).

The inter-location variation is explained both by the left leaflets (length, width and their ratio), right leaflets (length) (Table 2) and the first two pairs of leaflets petiole side (length and width). The width of the right leaflet distinguishes the localities of Sekoura M Daz that of Kandar Sidi Khiar; then the ratio of the length to

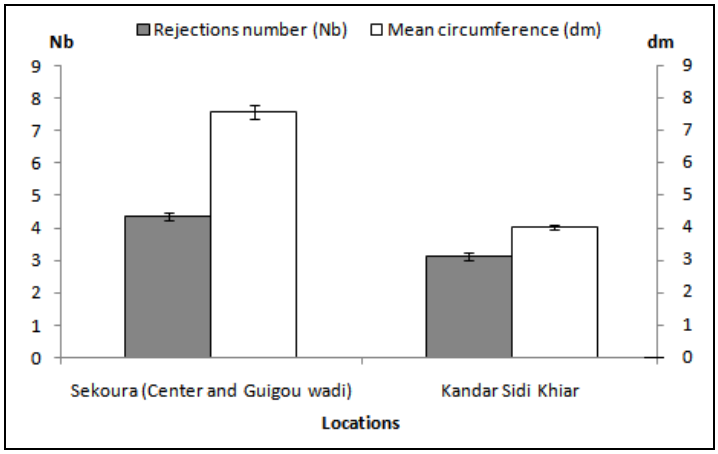

Figure 2. Rejections number and mean circumferonce of carob tree.

the width of the right leaflets has no discrimination in this respect (Table 3). Intra-location analysis of variance (ANOVA 95%) shows a very highly significant variation between trees of each location for all leaf and leaflets parameters studied. The variation of parameters monitored in the carob tree would be largely genotypically explained and secondly would be in relation to the provenance (location).

Trees from Sekoura M Daz (most favoured) have the most developed leaves: 14.5 cm long, 11.0 cm wide, 7 leaflets and 4.13 cm petiole length vs. 2l.9 cm long, l3.0 cm wide, 9 leaflets and 4.19 cm petiole length in the carob tree native of the province of Chefchaouen.

Table 2. Leaves characteristics according to locations. ANOVA to 95 %, N=1440. Values followed with the same letter are not significantly different.

Locations	Length (cm)	Width (cm)	Length/Width ratio	Petiole length (cm)	Leaflets number	Left leaflets number	Right leaflets number
Center of Sekoura	14.503 ±3.886	10.999 ±2.249	1.341 ±0.343a	4.125 ±1.282	7.075 ±1.494 a	3.408 ±0.789a	3.592 ±0.812a
Guigou wadi, Sekoura	13.610 ±3.582	10.573 ±2.283	1.330 ±0.477a	3.790 ±1.037	6.904 ±1.388 a	3.390 ±0.754a	3.51 ±0.711a
Kandar Sidi Khiar	11.382 ±3.117	9.379 ±1.915	1.293 ±0.373a	3.233 ±0.877	6.3±1.666	3.112 ±0.837	3.188 ±0.892
F ratio	70.714	72.796	1.911	83.862	34.451	20.89	33.572
P	5.106 E-30	0	0.148	0	2.432 E-15	1.14 E-09	5.628 E-15
Location effect	***	***	NS	***	***	***	***

Table 3. Leaflets average characteristics according to locations. ANOVA to 95 %, N=1440. Values followed with the same letter are not significantly different.

Locations	Left leaflets (cm)			Right leaflets (cm)		
	Length	Width	Length/Width ratio	Length	Width	Length/Width ratio
Center of Sekoura	5.532 ±0.991	3.554 ±0.654	1.57 ±0.199	5.567 ±0.956	3.592 ±0.812a	1.632 ±0.194a
Guigou wadi, Sekoura	5.259 ±0.971	3.184 ±0.574	1.662 ±0.211	5.280 ±1.026	3.51 ±0.711a	1.646 ±0.216a
Kandar Sidi Khiar	4.674 ±0.877	2.875 ±0.576	1.643 ±0.214	4.623 ±0.862	3.185 ±0.894	1.644 ±0.228a
F ratio	102.76	152.589	25.775	124.579	33.894	0.58
P	0	0	1.005 E-11	0	4.136 E-15	0.56
Location effect	***	***	***	***	***	NS

The ratio of length to width of the leave ranges from 1.29 to 1.34 for the Province of Sefrou, and 1.66 to 1.75 for the Province of Chefchaouen (Tables 1 and 4). The length and the average width of the leaflet also reach their maxima at these two locations, with 5.57 cm and 3.59 cm, vs. 5.92 cm and 3.65 cm in the same order for the carob tree native of the province of Chefchaouen. The ratio of length to width of the leaflet is 1.57 to 1.66 for the Sefrou Province (Table 2), and 1.52 to 1.66 for the Chefchaouen Province (Tables 2 and 4).

The carob tree native of the Sefrou Province appears to be less maintained, with shorter leaves, fewer and narrower leaflets, and similar petiole length in comparison with the carob tree native of the Chefchaouen Province. By the same logic, the leaves are more rounded; the leaflets are slightly shorter and narrower, but they have a similar shape.

Table 4. Compared characteristics (Minimal Mean / Maximal Mean) of Carob tree according to locations in the Sefrou Province and depending on location, category and year in the Chefchaouen Province.

	Sefrou Province	Chefchaouen Province	References
Leave			
Length (cm)	11.4 / 14.5	16.8 / 21.9	
Width (cm)	9.38 / 11.0	9.88 /13.0	
"Length/Width" ratio	1.29 / 1.34	1.66 / 1.75	
Leaflets number	6.30 / 7.08	7.31 / 8.59	The present study, Gharnit (2003), Gharnit *et al.* (2005)
Petiole length (cm)	3.23 / 4.13	3.51 / 4.19	
Leaflet			
Length (cm)	4.62 / 5.57	4.57 / 5.92	
Width (cm)	2.88 / 3.59	2.78 / 3.65	
"Length/Width" ratio	1.57 / 1.66	1.52 / 1.66	
Inflor-/Infrutescence			
Length (cm)	5.12 / 5.81	4.37 / 6.12	The present study, Gharnit (2003), Gharnit *et al.* (2004, 2010)
Flowers number	21.2 / 23.5	28.9 / 42.2	
Aborted flowers number	16.6 / 19.4	28.0 / 35.3	
Developed fruits number	4.01 / 4.62	2.87 / 4.96	

Efflorescence

The sex ratio, expressed as the ratio of numbers of males to female trees, is 1.23 and 1.04 respectively for the locations of Sekoura M Daz and Kandar Sidi Khiar. This shows that the grafting of male trees and female trees with low yields of carob bean is quite absent in the Sefrou Province, unlike the province of Chefchaouen, where grafting is practiced intensively (Gharnit *et al.*, 2004). Non flowery trees represent 3.33 % and 3.13 % in the same order. These trees can be below flowering age as they can be sterile as it was reported by Gharnit *et al.* (2001) and Gharnit (2003).

The numbers of aborted flowers and fruits per inflorescence group both the Sekoura M Daz, and Kandar Sidi Khiar locations. The length of the inflorescence isolates Oued Guigou - Sekoura and gathers Sekoura Centre and Kandar Sidi Khiar locations. However, regarding the number of developed fruits per inflorescence there were no differences between all locations (Table 5).

Intra-change locations (95% ANOVA), between the trees of a same location is very highly significant for all floral and fruiting parameters (Sekoura Centre), for the length of the inflorescence and the number of developed fruits (Oued Guigou - Sekoura), and for the length of the inflorescence and the numbers of flowers and fruits aborted (Kandar Sidi Khiar). In addition, highly the length of the inflorescence is, the greater the rate of flower abortion is (high correlation $p < 0.05$).

This variation is significant for the rate of the aborted fruit in Oued Guigou - Sekoura; while it is not significant for numbers of flowers and fruits aborted (Oued Guigou - Sekoura) and neither for

aborted fruit rate nor for the number of developed fruits (Kandar Sidi Khiar). As emphasized by (Gharnit *et al.*, 2004, 2010); location conditions do not explain the very highly significant differences of floral quantitative parameters (length of the inflorescence and number of flowers per inflorescence) and fruiting (aborted flowers and developing fruit rate). Both, the average length of the inflorescence and the number of flowers per inflorescence vary from 5.12 to 5.81 cm and from 21.2 to 23.5 flowers vs. 4.37 to 6.12 cm and 28.9 to 42.2 flowers, successively, when compared to the carob tree native of the Province of Chefchaouen (Tables 4 and 5).

Table 5. Quantitative characteristics of female or polygamous inflorescence according to locations. ANOVA to 95 %, N=1350. Values followed with the same letters are not significantly different.

Locations	Length (cm)	Flowers number	Aborted flowers number	Developed fruits number
Center of Sekoura	5.718 ±2.575a	23.448 ±10.776a	19.032 ±11.043a	4.416 ±3.800ab
Guigou wadi, Sekoura	5.121 ±1.997	23.384 ±8.817a	19.376 ±9.095a	4.009 ±2.774a
Kandar Sidi Khiar	5.808 ±2.027a	21.233 ±12.355	16.611 ±11.687	4.622 ±4.263b
F ratio	12.769	6.192	8.982	3.267
P	3.20819E-06	0.002104659	0.00013328	0.038629388
Location effect	***	**	***	*

The aborted flowers number per inflorescence varies from 16.6 to 19.4, slightly lower than the values recorded in the carob from the Province of Chefchaouen (28.0 to 35.3) (Tables 4 and 5). Moreover, the flowers abort probably because of adverse weather conditions, failure of fertilization or poor pollination at the tree level (Nettancourt, 1979).

The developed fruits number per infrutescence varies from approx. 4 to 5 vs. Approx. 3 to 5 for the carob tree native of the province of Chefchaouen (Tables 4 and 5).

Conclusion

This study showed that the carob tree native of the Sefrou Province is neither regularly pruned nor cultivated or grafted. The variation in leaf and leaflet parameters seeing in the carob tree would largely have a genotypic origin and secondly, it would be in relation to the origin (location). Considering the relative soil, weather and conservation characteristics of the studied locations, site conditions alone would not explain also the very highly significant differences seeing in floral and leave quantitative parameters. When compared to the Pre-Rif (Province of Chefchaouen), the carob tree native of the Sefrou Province (Middle Atlas) has shorter leaves, narrower and more rounded, with less numerous leaflets, shorter and narrower, and a similar length of petiole.

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