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Evaluation of the Phytomass of the *Pistacia lentiscus L.* for Rational Exploitation of Natural Resources in A Peri-Urban Forest of Algiers

Safia Abla, Ouahid Zanndouche[1] and Fatiha Abdoun[2]

Faculty of Sciences, University of Algiers 1 Benyoucef Benkhedda, Algiers-Algeria
[1]National Forest Research Institute (INRF), BP 37, Chéraga, 16014, Algiers-Algeria.
[2]Laboratory of Plant Ecology and Environment, Faculty of Biological Sciences, University of Sciences and Technology Houari Boumediene USTHB, PoBox 32, El Alia, Bab Ezzouar 16111, Algiers-Algeria
E-mail: abla.fac@gmail.com

***Abstract*:** In Algeria, the *Pistacia lentiscus* L. is widely used in different industries. Its uncontrolled exploitation threatens its sustainability. In the peri-urban forest of Baïnem, the most important one in the capital Algiers and are witnessing degradation for several years by a strong exploitation for the benefit of small and medium-sized enterprises. This exploitation does not follow any sustainable management strategy. We measured the production of phytomass and essential oil in order to develop a rational management protocol for the exploitation of the lentisk pistachio tree. Ten productive facies are identified based on their floristic compositions, structures, and dynamic states: 4 matorrals and 6 types of reforestations. A significant variability of phytomass and essential oil production is noted between the different facies according to the density of the undergrowth. Exploitation classes are identified according to the facies and their respective productions. This protocol could be applied in the Mediterranean forests of North Africa.

Keywords: *Pistacia lentiscus* L., Aerial phytomass, Essential oil, Peri-urban forest, Baïnem, Algiers

Algiers, the capital of Algeria in continuous development, tends to be a large metropolis and natural spaces are reducing. The peri-urban forest of Baïnem remains the most important green space (Plate 1) and endowed with a much diversified biodiversity that conceals threatened species such as Onopordum Algerians (Munby) Pomel (Djelid and al 2020). The biodiversity it contains is an important component in studying the functioning of all natural and human made ecosystems (Pandiarajan and al 2019). This forest ecosystem contributes directly and indirectly to the well-being of the Algerian population. It is a forest that has always been historically exploited for its wood, its medicinal, and food species including the *Pistacia lentiscus* L. of family Anacardiaceae, and widespread in the Mediterranean basin, growing in the wild in scrub (maquis) and garrigues in all types of soils, although it prefers siliceous grounds (Bereksi Reguig and al 2021). Common in the thermo-Mediterranean zone (Benmehdi and al 2013). Furthermore, *Pistacia lentiscus* L. has been known for its medicinal properties since ancient times (Beldi and al 2021). Also called the mastic tree, its resin was used to make chewing gum for gums, for the relief of abdominal pain, stomach ache, dyspepsia, and peptic ulcer (Soulaidopoulos and al 2022), for the treatment of gastrointestinal disorders (Vasiliki and al 2020). Essential oil is one of the main components reported for different parts of the Pistacia species (Bozorgi and al 2013). The collection and the anarchic uprooting of the *Pistacia lentiscus* L. constitute a serious threat to the habitats which it forms and which welcome a diverse fauna. Its formations have suffered a strong degradation for the production and marketing of essential oil. The exploitation is not subject to any regulation. To our knowledge, no study is reported of the exploitation of the *Pistacia lentiscus* L. nor any measure to make it less anarchic. This has led us to undertake an estimate of production to have data that can develop a regulation and a specification of exploitation for the preservation of the resource. The study aims at estimating the potential quantity of the phytomass of the *Pistacia lentiscus* L. to be taken without affecting the biological potential of the shrub at the level of the various facies previously recognized. It also aims to facilitate the respect of its exploitation charges by the operators by defining production classes according to the facies.

MATERIAL AND METHODS

Study area: The study was conducted in the peri-urban forest of Baïnem, which has a public domain status and is subject to the forestry regime and managed by the General Directorate of Forests, under the Ministry of Agriculture. It covers an area of 504 ha, in the Bouzaréah massif (Fig. 1).

Located 15 kilometers west of Algiers, in a coastal position less than 1 kilometer from the Mediterranean Sea. It represents the largest natural green space in the city of Algiers. The bioclimate is subhumid with hot winter. The highest point of the forest reaches 320 meters. Geologically, the terrain is diverse with the presence of metamorphic rocks (schists, micaschists, gneiss) (ISL-BRGM 2006). The Baïnem massif presents various natural forest and pre-forest formations (matorrals) with different facies based on *Pinus halepensis* Mill. and *Quercus suber* L. There are also plantations occupying a large area mainly with *Eucalyptus camaldulensis* Dehnh., *Eucalyptus gomphocephala* DC. , *Eucalyptus cladocalyx* F. Muell., *Eucalyptus leucoxylon* F.Muell. and *Acacia decurrens* (J.C.Wendl.) Willd.

Plate 1. Overview of the peri-urban forest of Baïnem

Fig. 1. Baïnem forest location map

Study method: The evaluation of the biomass of *Pistacia lentiscus* L. was done in spring, a period coinciding with the maximum production. Two methods were used, one direct, called destructive, and the other indirect, called allometric. These two methods lead us to measure the phytomass of the considered species. To do this, we first carried out 14 phytoecological surveys (Fig. 2) with an area of 400 m^2 representative of each visually recognized facies. In a second step, we stretched, in each survey area, a 20 m line to estimate the global cover. The latter will be used in the application of the indirect method by determining the measured cover-phytomass relationship.

Direct method: Along the 20 m line, we chose 10 m^2 to make the cuts on 50% of the surveys. To minimize the destructive effects of the method, a previous experiment where several sampling rates were tested on this species, led to determining the rate of 75% as a potential sampling threshold to not harm the good development of the sampled subjects and collected 75% of the plant material (twigs and leaves without fruit) from all the *Pistacia lentiscus* L plants on a 10 m^2 area. The aerial phytomass represents the quantitative expression of the vegetation at a given time and place, in the 10 m^2 of each plot with cutting (Nedjraoui and Touffet, 1994). The cut vegetation is sorted, possibly by separating living material from dead material or by separating leafy branches from wood. Once sorted, weighed on-site to determine its

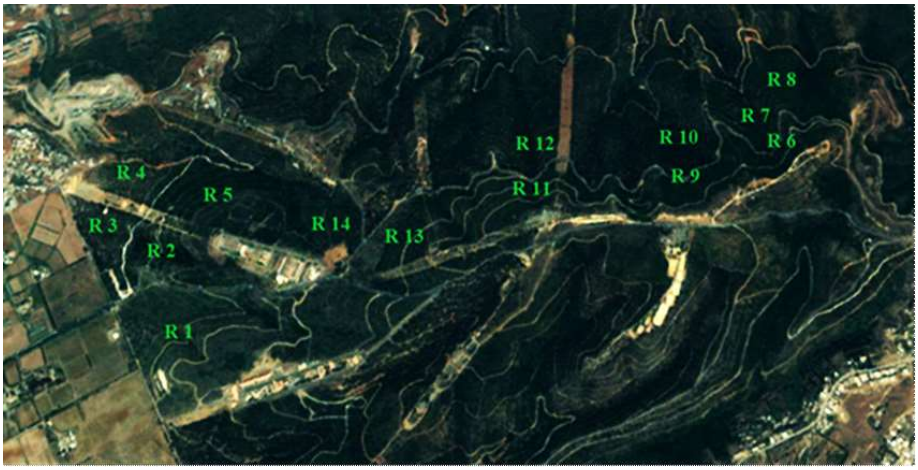

Fig. 2. Map of the location of the sampling plots

fresh weight. We then take a sample of known green weight, which will be placed in an oven at a temperature of 75-80°C for drying, for 48-72 hours (until constant weight) to obtain the dry matter (DM) weight following the formula (Honvou and al 2018) :

$$DM\ \% = \frac{\text{Dry weight of the sample}}{\text{Fresh weight of the sample}} \times 100$$

Indirect or allometric method: This technique is of very common use for the evaluation of phytomass in tree formations (Clifford and al 2013), allows the evaluation of phytomass using parameters that have a significant correlation with it. Based on the cover and the structure of the mastic bushes of the stations used for the direct method, we measured the cover of the species using the line method to estimate the biomass (Long and al 1970). The latter consists of setting up a device consisting of a graduated line represented by a 20 m long ribbon and taking readings along this line by pointing a needle at the elements of the soil surface and vegetation with a10 cm spacing between two readings. The frequency of a feature was recorded at 200 points which allowed for the measurement of vegetation cover and other soil surface features (Fig. 3).

Production of pistachio oil: The extraction of the essential oils was carried out by hydrodistillation of 100 g of samples of the leaves of the *Pistacia lentiscus* L during 2 h 30 mn using a system of "Clevenger" (Clevenger 1928). The distillation lasts three hours after the appearance of the first drop of distillate at the exit of the steam condensation tube. The essential oil content, expressed in ml of the distillate per 100 g of dry matter, is expressed by the following relationship.

$$THE = (V/DMX100) \pm (\Delta V/DM100)$$

THE: Content of essential oils, V: Volume of essential oils collected (ml), ΔV: Error on the reading, DM: Dry plant mass (g).

RESULTS AND DISCUSSION

The analysis of the phytoecological and linear surveys indicated 10 potentially productive facies. These facies are represented by 4 types of matorral and 6 types of plantation. These two physiognomic types cover 79 ha and represent nearly 16% of the total surface of the peri-urban forest of Baïnem (Table 1). The total production of phytomass exploitable area is estimated at 181485, 52 kg.dm with a production of essential oils of about 40 kg, the plantations produce 21, 52 kg while the natural matorrals produce 18, 64 kg. Phytomass and essential oil production per hectare at the matorral level are higher than at the plantation level (Table 2).

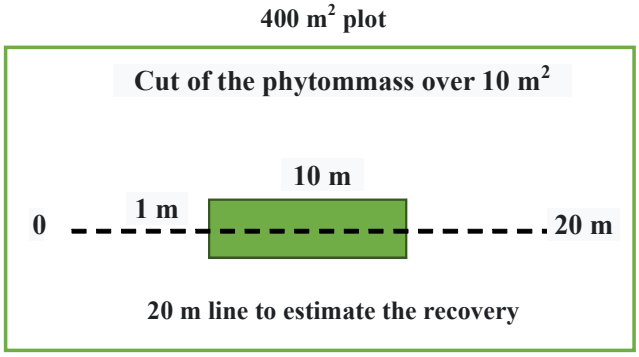

Fig. 3. Sample plot, linear survey, and cut surface

Table 1. Area of potentially productive and exploitable facies of *Pistacia lentiscus* L.in the Baïnem forest

Facies	Area (ha)
Facies 1 : Löw and moderately dense matorral with *Pistacia lentiscus* L., *Cistus monspelliensis*L. and *Olea europea subsp. europaea* L.	10,56
Facies 8 : Low and moderately dense matorral with *Pistacia lentiscus* L., Arbutus unedo L. and *Cistus monspelliensis* L.	5,22
Facies 5 : Low and dense matorral with *Arbutus unedo*,L.,*Pistacia lentiscus* L.,*Olea europea subsp. europaea* L., *Phillyrea angustifolia* L. and *Cistus monspelliensis*L.	3,08
Facies 9 : Matorral low and clear to *Quercus suber* L., *Arbutus unedo* L., *Pistacia lentiscus*L. and *Cistus monspelliensis* L.	9,12
Facies 4 : Plantation of *Eucalyptus camaldulensis*Dehnhwith dense undergrowth of *Pistacia lentiscus* L., *Calycotomespinosa* (L.)Link.and Cistusmonspellienis L.	9,04
Facies 3 : Plantation of*Eucalyptus bosistoana*F.Muell. a light undergrowth of *Oleaeuropea subsp. europaea* L., *Pistacia lentiscus*L.and *Cistusmonspeliensis*L.	4,2
Facies 10 : Plantation of *Eucalyptus cladocalyx*F.Muellwith moderately dense undergrowth of *Pinus halepensis*Mill. , *Pistacia lentiscus* L .,*Arbutus unedo*L. and *Myrtus communis* L.	1,72
Facies 6 : Plantation of *Pinus halepensis Mill* with a light undergrowth of*Olea europea subsp. europaea L., Arbutus unedoL.*and*Pistacia lentiscus L.*	5,84
Facies 2: Plantation of *Eucalyptus bosistoana*F.Muell.With moderately dense undergrowth of *Quercus suber* L.,*Olea europea subsp. europaea*L.,*Quercuscoccifera* L. and *Calycotome spinosa* (L.)Link.	4,32
Facies 7: Plantation with *Eucalyptus gomphocephala*DC.and*Pinus halepensis Mill.*with a light undergrowth of *Quercus coccifera*L.*, Arbutus unedo*L. and*Pistacia lentiscus*L.	26,04
Total exploitable area	79,14

Phytomass of *Pistacia lentiscus* L. in the matorrals: The total exploitable phytomass at the level of matorrals was estimated at 84292 kg of dry matter or 46.45% of the total production for an area of 27.98 ha. The quantity of phytomass produced per hectare varies from 4080 kgms/ha for the most productive facies 1 to 1060 kgms/ha for the least productive (facies 9). The phytomass produced by these matorrals can provide up to 18.64 kg of essential oil (Table 3).

Facies 1 covers 13,3% of the potentially productive area and is characterized by low, moderately dense matorral with *Pistacia lentiscus* L., *Olea europea subsp. europaea L.*, *Cistus monspelliensis* L., and *Myrtus communis* L.. This type of formation represents, in the Mediterranean region, regressive stages of forest ecosystems made up of sclerophyllous species that offer a heterogeneous physiognomic diversity (Thompson 2020). Together with facies 8 and 5, it forms formations composed of an undergrowth of species indicative of degradation, and where the *Pistacia lentiscus* L. is abundant ,which explains the high production of phytomass, which exceeds 3800 Kg.dm/ha (Fig. 4).

The matorral with *Quercus suber* L. (facies 9) is characterized by the lowest production compared to the other three and is just over 1000 Kg.dm/ha. This low production is essentially due to the low cover of *Pistacia lentiscus* L.. The presence of this species nevertheless characterizes degraded subterranean forests (Aime, 1976). Excessive logging may intensify the degradation of the undergrowth, the opening of the matorral, and promote therophytization (Barbéro and al 1990).

Phytomass of the *Pistacia lentiscus* L at the level of the plantations: The greatest quantity of the exploitable phytomass of the *Pistacia lentiscus* L. is at the level of the plantations with 97193, 52 Kg.dm distributed on a surface of 51,16 ha that is to say 64,64% of the exploitable surface and which can give more than 21kg of essential oil (Table 4).

Indeed, the plantations at the level of the forest of Baïnem are essentially constituted of Eucalyptus which occupy more than 50% of the total surface of the plant cover. These plantations do not favor the development of the undergrowth, hence a lower phytomass (facies 6, 2 and 7). However, the greatest production of exploitable phytomass per hectare is on facies 4, represented by the *Eucalyptus camaldulensis* Dehnh plantation with a dense undergrowth dominated by *Pistacia lentiscus* L.. This phytomass is evaluated at 5500 Kg.dm/ha or11,4% of the total production, which is explained by the abundance of *Pistacia lentiscus* L., which is in more than 60% of the total surface area of the facies with a coefficient of abundance dominance of 4 according to Braun Blanquet (1932), and where the production of essential oil exceeds 11 kg. These are old Eucalyptus plantations dating from 1956 that were thinned out in the 1990, which allowed the development of *Pistacia lentiscus* L. in abundance after the opening of the tree layer. The presence of *Calicotome*

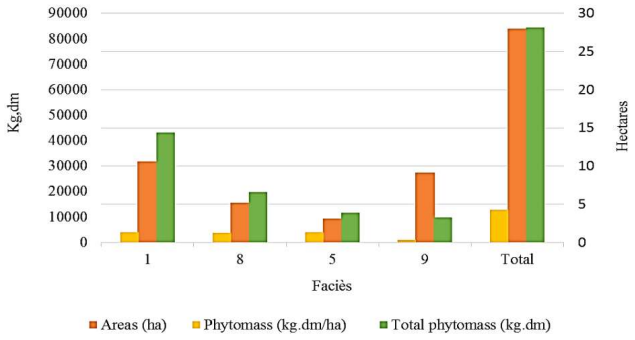

Fig. 4. Phytomass production by facies

Table 2. Usable phytomass and essential oil production of *Pistacia lentiscus* L.at the level of plantations and matorrals

Physiognomic types	Area (ha)	Average phytomass (kg.dm/ha)	Total phytomass (kg.dm)	Average essential oil production (kg / ha)	Total production of essential oils (kg)
Plantations	51,16	2 439,66	97 193,52	0,52	21,52
Matorrals	27,98	3210	84 292	0 ,69	18,64
Total	79,14	5649,66	181485,52	1,21	40,16

Table 3. Phytomass and production of essential oils of *Pistacia lentiscus* L. by facies on the matorral level

Facies	Area (ha)	Phytomass (kg.dm/ha)	Total phytomass (kg.dm)	Essential oil production (kg/ha)	Total production of essential oils (kg)
1	10,56	4080	43084,8	0.98	10.35
8	5,22	3800	19836	0.72	3.76
5	3,08	3900	11704	0.85	2.62
9	9,12	1060	9667.2	021	1.91
Total	27,98	12840	84 292	2.76	18.64

Table 4. Phytomass and production of essential oils of *Pistacia lentiscus* L by facies at the level of the plantations

Faciès	Area (ha)	Phytomass (kg.dm/ ha)	Total phytomass (kg.dm)	Essential oil production (kg / ha)	Total production of essential oils (kg)
4	9.04	5500	49720	1.27	11.48
3	4.2	3700	15540	0.67	2.81
10	1.72	2250	3870	0.51	0.87
6	5.84	1000	5840	0.23	1.34
2	4.32	1600	6912	0.32	1.38
7	26.04	588	15311.52	0.14	3.64
Total	51.16	14638	97193.52	3.14	21.52

Table 5. Phytomass production classes

Phytomass classes (Kg.dm/ha)	Facies	Production (Kg.dm/ha)
I : P> 5000	4	5500
II : 5000 > P > 4000	1	4080
III : 4000 > P> 3000	5	3900
	8	3800
	3	3700
IV : 3000 > P > 2000	10	2250
V : 2000 > P > 1000	2	1600
	6	1000
	9	1060
VI : P < 1000	7	588

spinosa (L.)Link.is the result of the degradation of the subterranean forests to the point of the disappearance of the cork oak and its usual cortège, and the installation of a flora belonging to other degraded groupings. The degradation of this grouping is followed by an opening of the tree and shrub stratum as evidenced by the presence of *Pistacia lentiscus* L . and which also reflects the high and regular frequency of fires.

The *Eucalyptus bosistoana* F.Muell plantation (facies 3) is also characterized by a fairly high phytomass production reaching 3700 Kg.dm/ha. Facies 10, on the other hand, covers the smallest exploitable area and is represented by the *Eucalyptus cladocalyx* F. Muell plantation, producing 2250 kg.dm/ha. It is characterized by a moderately dense undergrowth of *Pinus halepensis* Mill.,*Pistacia lentiscus L.*, *Arbutus unedo* L., and *Myrtus communis* L. Facies 6 has a total essential oil production of 1,34 kg or 0,23 kg/ha. These last facies with facies 2 produce a phytomass equal to or greater than 1000 kg.dm/ha which is much greater than that produced by the mixed plantation of *Eucalyptus gomphocephala* DC. and *Pinus halepensis* Mill.(facies 7). This latter plantation occupies the largest area with 26, 04 ha but with the lowest production, which is around 588 kg.dm/ha. The coverage of the tree stratum formed by Eucalyptus and Aleppo pine means that the development of the undergrowth is very low, hence the low production of the phytomass of the *Pistacia lentiscus* L. The low coverage of the latter is also due to the overexploitation of this species by the pickers (the removal exceeds 75%).

Proposal of exploitation classes: Six classes are defined by the interval of phytomass produced across the different facies (Table 5). This classification is proposed for use in the management of *Pistacia lentiscus* L. leaf collection. This proposal remains dependent on the dynamics of this peri-urban natural space. Although it has a recreational vocation, the Baïnem forest is subject to frequent fires. The rainfall regime, concentrated over two seasons, causes significant flooding that can lead to soil erosion when it occurs after the fire. The opening of the forest and pre-forest cover, the consequence of these elements, favors to a certain degree the installation and the extension of the *Pistacia lentiscus* L.

CONCLUSION

Algeria still lacks a lot of data on the current state of plant biodiversity of peri-urban forests and its exploitation. However, certainly, the absence of this kind of information does not facilitate the task of managers. This work is the first of its kind in this forest, so the results obtained are a source of information for managers. It poses a new problem for scientists and users. The implementation of a management plan would contribute to the safeguard of this shrub object of exploitation and the fauna and flora of which it constitutes the habitat.

This study shows the production capacity of the forest of Baïnem in terms of phytomass and therefore the profitability that *Pistacia lentiscus* L. offers by its oil which is one of the most expensive on the international market. These results will make it possible to set up specifications for the exploitation of lentisk in the Baïnem forest but also can be used elsewhere in the same thermo-Mediterranean facies. The preservation and development of this resource require the implementation of rational exploitation methods and a participatory management.

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