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Research Article

IMPACT OF TREE VIGOR ON THE ANNUAL INCREASE OF CORK IN THE CORK OAK FOREST OF MAMORA (MOROCCO)

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ABSTRACT

The purpose of this study was to monitor the annual evolution of the thickness of cork in ten settled plots at the forest of Mamora, and to analyze how much this annual growth is influenced by different tree vigor's of a stand of cork oak.
The following study was conducted on a sample of 200 cork oak tree that belongs to the monitoring plots of the health of the Mamora forest. The vigor of these trees was assessed annually according to the guide of forest health related to the decision of silvicultural operations at the cork oak forest of Mamora. The annual monitoring studies of the cork thickness was carried out during three seasons (2011, 2012 and 2013) by using a probe specific to this kind of meticulous measurement.
The study has identified: the annual growth of the thickness of cork per tree and the annual growth of the thickness of cork per plot. The plot P9 has shown the highest annual growth with a growth rate of around 3,215 mm/year. The trees of this plot are mostly healthy. Whereas the plot P1 has shown the lower annual growth, with a growth rate of around 1,374 mm/year. This plot brings together mostly stable trees which are suffering or in degradation.
Sustainable management cannot be achieved without acquiring a set of tools and means for monitoring and surveillance of our Moroccan forests; in order to take appropriate decisions at the right time. Thereby, this work tries modestly to introduce the education of monitoring to forest managers and deduce useful parameters for good forest management.
This study provides through monitoring of the annual growth average, the plots to remove in a stand, to define the exact debarking's year of each plot and assess cork production in quantity and quality during a season.

INTRODUCTION

The Mediterranean forests cover approximately 81 million hectares (9.4% of the forest area in the world) and are composed of a mosaic of forest tree species, mainly deciduous (approximately 60%) (Mugnossa *et al.,* 2000). The cork oak is among the species endemic to the Mediterranean basin that extends on a global area of 1.964.000 ha. Portugal is the country which occupies the largest area (33%), then comes Algeria (22%), Spain (17%) and in the fourth position comes Morocco with 16% of the global area of cork oak.

The cork oak forest produce a large quantity of cork (approximately 300 million kg per year) (Lopes, 1996; Santos Pereira *et al.,* 2008). This natural product knows, sometimes, during the process of its training, disturbances that affect its growth, color, texture, density and the frequency of its porosity (Molinas and Oliva, 1990).

However, despite the resistance of cork oak trees, reported through the work of several authors (Oliveira *et al.,* 1992; Molinas and Verdaguer, 1993; Caritat *et al.,* 1996). This last has been weakened in recent decades as a result of succession of dieback. This general phenomenon, which concerns most cork oak Mediterranean's countries, is not a very precise concept. It is difficult to explain in a satisfactory manner the exact origin and the specific causes of the phenomenon. Indeed, the decline of the cork oak is a gradual process involving several factors sequentially or simultaneously leads a progressive decrease of the vigor's trees (Sousa, 2005).

Many are the authors who have referred to tree's growth in relation with the physical environment and circumstances climate (Fritts, 1976; FOS *et al.,* 1994; Costa *et al.,* 2002; Vazquez-Piqué *et al.,* 2008). Others are interested in studying the process of training the annual increase of cork and have proposed a commercial classification to each thickness of cork, similar to each ecological zone and of production (Lamey,

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1893; Saccardy, 1937; Boudy, 1950 and Natividade, 1956). Very rare, are the work who are interested in the impact of forest decline on the growth of cork.

The present work seeks to define in what proportion the annual growth cork's tree is influenced by the different situations of vigor trees in the stand of cork oak (stand in improvement, stable in health, stable in suffering and stand in degradation). It is also included in the continuity of monitoring of vigor trees, with a visual symptomatological description (Hamidi and *al.,* 2014).

MATERIALS AND METHODS

In Morocco, the cork oak extends in the north-western part since the plains of the coastline until the central Rif and the middle Atlas. Formerly, the cork oak occupied in Morocco a considerable area. Natividad (1956) spoke, there are four thousand years, about 5 million hectares of forest, extending from the Atlantic coast up to the foothills of the Atlas Mountains to the south of Marrakech, which testify, the many bouquets relics listed by Sauvage (1961).

Mamora is the largest extended of cork oak in Morocco, with an area of 131.758 ha. It is present in an elongated shape with a length of 70 km and a width of 40 Km. This forest is mounted on a total of five cantons (A, B, C, D and E) that follow approximately a West-East direction and which are divided by the beds of the main rivers that crisscross the forest.

In this forest, several research works have been carried out particularly on the cork oak. However, studies referring to the technology of the cork (increase and quality) in relation with the ecophysiology of trees are little discussed in Morocco and remain a discipline very ignored as elsewhere. As well, the objective of the present work is to highlight the impact of different trends of dieback (stand in improvement, stable in health, stable in suffering and stand in degradation) on the annual growth of cork. To this effect, 10 plots belonging to the network of monitoring forest health of the Mamora have been retained and materialized to serve later to collecting different information for this study.

In a first time, the 20 trees of each plot were the subject of a careful control of the basis to the height of 1.30 m.

Table 1 Evolution of vigor trees (2011 to 2013).

	Trend of evolution of dieback (in % of trees).			
P1	Improvement	Stable in Health	Stable in suffering	Degradation
	40	10	35	15
P2	Improvement	Stable in Health	Stable in suffering	Degradation
	10	45	10	35
P3	Improvement	Stable in Health	Stable in suffering	Degradation
	45	30	10	15
P4	Improvement	Stable in Health	Stable in suffering	Degradation
	50	25	10	15
P5	Improvement	Stable in Health	Stable in suffering	Degradation
	85	15	0	0
P6	Improvement	Stable in Health	Stable in suffering	Degradation
	30	35	25	5
P7	Improvement	Stable in Health	Stable in suffering	Degradation
	40	40	5	15
P8	Improvement	Stable in Health	Stable in suffering	Degradation
	30	25	20	25
P9	Improvement	Stable in Health	Stable in suffering	Degradation
	100	0	0	0
P10	Improvement	Stable in Health	Stable in suffering	Degradation
	40	25	35	0

We have taken into consideration, the straightness of the trunk and the absence of abnormalities of growth on the keg.

Then, an assessment of each plot, according to the guide of forest health in relation with a decision of the harvesting cork in Mamora (Hamidi and *al.,* 2014), has been initiated to define the level of dieback installed. The table n°1 reminds the state of trees' health in each plots of the study (as a percentage of the trees).

The annual average increase per tree and the annual average increase per plot, two important parameters for this research work, are calculated from the annual measures of cork thickness carried out using a cork probe specific to this kind of meticulous measurement, during the 3 seasons of study 2011, 2012 and 2013.

RESULTS AND DISCUSSION

The annual average increase per tree as well as the annual average increase relating to each plot is shown in the table n°2.

Table 2 Percentage of trees by class of annual average increase and annual average increase of each plot in mm.

	Percentage of trees by annual average increase				**Annual average increase of plot in mm**
Point of control	**0,8-1,5 Mm**	**1,51-2 Mm**	**2,1-3 Mm**	**>3 Mm**	
Median	**1,15 mm**	**1,755 mm**	**2,55 mm**	**3,5 mm**	
P1	20	30	35	15	1.374
P2	45	35	10	10	1.736
P3	20	20	45	15	2.253
P4	25	30	25	20	2.151
P5	5	25	45	25	2.51
P6	30	45	10	15	**1.914**
P7	50	20	20	10	1.786
P8	40	35	25	0	1.711
P9	0	0	30	70	3.215
P10	35	40	15	10	1.837

This table shows, on the one hand, that the highest average annual growth rate per plot is that of the P9 plot, with a growth rate of around 3,215 mm/year. This rate very fast belonging to class n°3, according to the commercial classification proposed by Lamey (1893) and Boudy (1955) in table n°3. In term of vigor tree, this plot is at 100% of the trees in improvement (Hamidi and *al.,* 2014). On the other hand, the lowest rate of annual average increase per plot is that of the P1 plot with a growth rate of around 1.374 mm /year. This rate of annual increase is considered low (class 1) according to the same classification (Lamey, 1893 and Boudy, 1955). This plot is at 50% of the trees, either by degradation or stable in suffering (Hamidi *et al.,* 2014).

The P6 plot present always a particular situation, it has been defined according to the guide of forest health in relation with a decision of the harvesting cork in Mamora (Hamidi and *al.,* 2014) as a plot limit of tolerance to supporting silvicultural activities. In this study, it is also intermediate between plots having, medium to very fast, rate of annual increase and those having low to medium, rate of annual increase. This plot with a growth rate of around 1,914 mm per year belongs to the class 2 (Medium) following the proposal of Lamey (1893) and Boudy (1955) (Table n°3).

Table 3 Main classes increases annual means of cork and type of cork correspondent (Lamey, 1893; Boudy, 1955)

Class	Limit of increased	Type of increase
1	0.8-1.5mm	Reliable
2	1.51-2 mm	Medium
3	2.1-3 mm	Fast
4	>3 mm	Very fast

The plots studied can be divided into two groups: The first one, regrouping plots P1, P2, P8 and P10, it presents the lowest annual growth increments means, with a minimum of 1,374 mm per year for the plot P1 and a maximum of 1,873 mm per year for the plot P10. This continuous decrease of the annual increments of cork is responsible for the reduction of the corky production of trees and stands. It is linked to several factors of the environment in which evolve the trees. Since 1980, the scientists associate the decline of production of the Mediterranean corky to the degradation of the state of health of the trees (Mattson and Haak 1987; Becker, 1987). This result is also confirmed in this study because this group of plot (P1, P2, P8 and P10) is defined according to the guide of forest health in relation with a decision of the harvesting cork in Mamora, as being the group of plot having the Important rate of declining trees (Hamidi and *al.*, 2014).

The second group contains the plots P3, P4, P5, P6, P7 and P9; it presents the highest rate of annual growth increments means, with a minimum of 1,914 mm per year for the plot P6 and a maximum of 3,215 mm per year for the plot P9. This group of the plots is described, according to the same health guide (Hamidi and *al.,* 2014), as being of the plots in dominance of stable trees in health or improvement.

This study confirms the serious relationship between the health of the trees of cork oak and the growth of cork. She joined the result obtained by Dahane in 2006, who has deducted in conclusion of its work of research that in a adequate sanitary situation the rings growth of the cork are fast to very fast for vigorous trees (>2.5mm per year) while they are medium to low for the declining trees (<2.5 mm per year).

Figure 1 Operation of measurement of the thickness of the cork.

According to Costa and *al.* (2002), this situation is explained by the deficient health status, characterized by the associated or separate interference for many factors (soil texture, prolonged drought, competition of the under wood and other essences, incorrect exploitation and insect attack). Indeed, the trees lose their physiological capacity to meet its various productive organs, such as cambium, phellogen, adventitious buds and terminal. Given that the production of cork owns 70% of the growth of the cork oak during the vegetative cycle of the trees, the species reacts negatively by decreasing the thicknesses of the corky rings for the benefit of the other organs.

However, the annual monitoring of the average increase is important to define the thickness of the cork at the end of a production cycle. Also called commercially caliber of cork, it represents the quantitative side of the quality (quantity of plugs or disks product per kilogram on a plank of cork). It conditions at the same time, the duration of the production cycle in cork oak and defines the classes of thicknesses commonly admitted by the trade as indicated on the table n°4.

Table 4 Important classes of thickness's cork and kind of cork corresponding to international standards (NP 298, 1993).

Class	Limit of thickness	Kind of cork
1	<22 mm	Floating
2	22-27 mm	Minced
3	27-32 mm	Just
4	32-50 mm	Regular

The caliber of cork is one of the parameters that has an important influence on the performance of a cork oak and therefore determines the different industrial applications of the raw material. As an indication, the production of plugs (24 mm diameter minimum) needs at least 27 mm as a thickness of cork; this production would be increased if the caliber oscillated between 29 and 33 mm. Contrary to this, a lower caliber to 27 mm, requires us to orient the raw matter for manufacturing of minor value products (washers), while the boards with the caliber superior than 40 mm contain a high rate of loss (waste). This situation can only be rectified by a redistribution of the boards by category or class of uniform thickness to industry standards (Gonzalez-Adrados and *al.,* 2000).

CONCLUSION

In order to evaluate the quality of the cork; we must inevitably passes through the knowledge of all the characters and properties that affect its ability to transform into the plugs or washers. This capacity is linked to many factors, that the thickness of the board of cork is the most important (Foucault, 1997).

Thus, the calculation of the annual average increase of cork represents an important parameter in cork oak management, because it regulates the operations of exploitation and subsequent uses of cork. Nevertheless, this quantity of cork produced during 7 months of each year is not always stable; it obeys the calamities of the physical environment which are subject trees. The results of this study confirm the direct influence of phytosanitary circumstances and the level of dieback installed on the development of the trees of cork oak in general and on the average annual increase in the thickness of the cork in particular.

However, we don't know the really contribution for the genetic and environmental components, or of their interactions, in the determination of the growth of this product, although the great variability between trees suggests a strong intervention of the genetic factor.

As a recommendation, it is always desirable that forestry staff performs the monitoring of the annual average increase for a better management of Moroccan cork oak. A tell indicator will also help us to know the number of trees accurate to lifted in a stand, to define the year of specific debarking to each parcel and to assess the production of cork in quantity and quality in a campaign.

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