Silva Lusitana ***12****(1): 15 - 23, 2004*

Tree Profile of Littoral Portuguese Maritime Pine

Mário Tavares* and José Campos**
*Senior Researcher
**Forest Engineer
Estação Florestal Nacional. Departamento de Silvicultura e Produtos Florestais, Av. da República, Quinta do Marquês, 2780-159 OEIRAS

Abstract. *Pinus pinaster* Aiton is ecologically well adjusted to the Portuguese west littoral sands. The silviculture of this species in even aged, high forest stands produce tall, large trees, showing very peculiar technological characteristics.

Within maritime pine stands, selective low thinning promotes the segregation of three main representative tree hierarchic statutes - dominated, medium and dominant. These statutes, tree age and spacing, original sample site and some artificial pruning applied during youth, have some influence in the dimensional partition of tree profiles into three parts, namely crown occurrence and vitality - alive and dead crown and clear trunks.

A sample of 96 trees chosen from three Portuguese west littoral forests was divided equally into those three statutes and was used to evaluate their mean sizes and to model their relationship with those factors.

Main results are (a) the size of live crown increases with tree statute inside the stand, (b) for a given age, tree statute does not determine significant differences in dead crown depth, and (c) the main trunk depth tends towards the highest values in the medium trees. Furthermore, (d) live crown depth is independent of provenance and hierarchic factors, (e) the northern littoral region trees exhibit the biggest crown depths, (f) dominant trees tend to exhibit smaller main trunk depth and (g) artificial pruning must be applied as high as possible up the main trunk.
Key words: *Pinus pinaster*; age; tree spacing; statute; tree profile

Perfil da Árvore de Pinheiro Bravo do Litoral Português

Sumário. A *Pinus pinaster* Aiton é uma espécie bem adaptada às areias do litoral oeste Português. A silvicultura desta espécie em povoamentos equiénios e de alto fuste origina árvores de grandes dimensões com características tecnológicas singulares.

Nos povoamentos de pinheiro bravo os desbastes pelo baixo e selectivos, promovem a segregação das árvores em três estatutos hierárquicos principais - dominada, média e dominante. Estes estatutos, a idade das árvores e o compasso, a proveniência e a desrama artificial efectuada nas fases mais jovens dos povoamentos, têm alguma influência na repartição dimensional do perfil da árvore em três partes, relativamente à presença e vitalidade da copa - - copa viva e morta e tronco limpo.

Uma amostra de 96 árvores provenientes de três matas do litoral oeste Português foi equitativamente repartida por aqueles três estatutos e utilizada para avaliar as suas dimensões

Corresponding Author E-mail: mario.tavares@efn.com.pt

médias e para modelar a sua relação com aqueles factores.

Os principais resultados são que (a) a dimensão da copa viva aumenta com o estatuto da árvore no povoamento, (b) para uma dada idade, o estatuto da árvore não determina diferenças significativas na profundidade de copa morta, e (c) a profundidade de tronco limpo atinge valores mais elevados nas árvores médias. Também que (d) a profundidade de copa viva se revela independente da proveniência e da hierarquia, (e) as árvores da região litoral norte apresentam as maiores profundidades de copa, (f) as árvores dominantes tendem a apresentar menores profundidades de tronco limpo e que (g) a desrama artificial deve aplicar-se o mais alto possível no toro da base.

Palavras-chave: *Pinus pinaster*; idade; espaçamento; estatuto; perfil da árvore

Profil de l'Arbre de Pin Maritime du Littoral Portugais

Résumé. La *Pinus pinaster* Aiton est une essence bien adaptée aux sables du littoral portugais. La sylviculture de cette essence dans des peuplements en futaies régulières origine des arbres à grandes dimensions avec des caractéristiques technologiques singulières.

Les éclaircies par le bas et sélectives dans les peuplements de pin maritime, poussent en avant la ségrégation des arbres en trois statuts hiérarchiques principaux – dominée, moyen et dominant. Ces statuts, l'âge des arbres et la circonférence, la provenance et l'élagage artificiel effectuée pendant les phases plus jeunes des peuplements, ont quelques influences sur la répartition dimensionnelle du profil de l'arbre en trois parties, par rapport à la présence et vitalité du houppier – houppier vivant et mort et tige nette.

Un échantillon de 96 arbres provenant de trois forêts du littoral Ouest du Portugal a été équitablement réparti en ces trois statuts et utilisé pour évaluer ses dimensions moyennes et pour modeler sa relation avec ces autres facteurs.

Les résultats principaux sont que (a) la dimension du houppier vivant augmente avec le statut de l'arbre dans le peuplement, (b) pour un âge donné, le statut de l'arbre ne détermine pas de différences significatives dans la profondeur du houppier mort, et (c) la profondeur de la tige nette atteint des valeurs plus élevées sur les arbres moyens. De même que (d) la profondeur du houppier vivant se révèle indépendant de la provenance et de la hiérarchie, (e) les arbres de la région littorale Nord présentent les plus grandes profondeurs du houppier, (f) les arbres dominants tendent à présenter des profondeurs plus petites de tige nette de branches et (g) que l'élagage artificiel doit s'appliquer le plus haut possible sur le billon de la base de l'arbre.

Mots-clés: *Pinus pinaster*; âge; espacement; statut; profil de l'arbre

---

Introduction

Forestry and in what it relates to genetic, edaphic, climatic and biotic causes will have significant influence in the control of wood variability, particularly in what concerns the reflection of this variability in the defects of round and sawn wood.

While dealing with littoral pine stands, mostly state forests, and that they present very uniform management models. They are settled on pure and even aged stands, managed in high stand. The oldest ones were seeded and the youngest are natural regeneration or plantings. Land preparation is always slight, and brushes control is very regular.

Silvicultural cuts generally follows pre-defined management plans or, at least, conducting or cutting plans well staggered in time. Pruning is just done in the live crown, twice until 3m high – the first one at about height years old, and the second one at the beginning of high stand. In the old trees pruning was applied at a higher level – 7 m and more.

All these aspects take place without precise registers or even with registration of several types of silvicultural operations. So, everything told about the influence of these production factors on wood quality always contains some degree of speculation.

In this context, an approach is made on the architectural variability of Portuguese littoral maritime pines, in connection with some silvicultural and growth aspects.

While contained in reasonable limits, adjusted aerial and rooting space partition, as a mean to reach a balanced and efficient soil profile colonisation (MÁTYÁS and VARGA, 2000), points out the need to get adjusted crown sizes to the main stem length. This is also the way to reach an equilibrated light and physical use, and the adequate partition of subterraneous space, mainly the superficial layer, where nutrients, airing and moisture are available (TAVARES, 1989, 1999).

Incoming site productive potential has been sustained by thinning and pruning operations done in correct time (CAMERON, 2002). This silvicultural practice is the one that can reach the necessary equilibrium. It happens in order to get a bigger quantity of wood biomass in the stem; however, the whorls branches should never achieve exaggerated sizes. So, big dimension trees with a thin-knotted core, better pit centrality, small reaction wood, and balanced juvenile wood can be realized (ZOBEL and BUIJTENEN, 1989). Also with better physical and chemical performances, dimensional regularity of annual growth rings and an improved earlywood/latewood ratio relationship will also happen, with small number and size of knots, and eventually higher predominance of sound knots.

All these aspects get better performance on sawn wood, and are most supported in silviculture and forest management, namely in the plants per hectare control during their life and the crown dimensions control of the remaining trees (Amarasekara and Denne).

Materials and methods

The variables used in this study were estimated from 32 plots installed in 32 maritime pine stands belonging to three state forests – 10 in Camarido National Forest (CNF), 12 in Leiria National Forest (LNF), and 10 in Comporta Forest (CF). Stands were between 9 and 73 years old.

The mean spacing (sp) was evaluated using the distances, in meters, between each tree axe and its four closest trees.

The age (t) was estimated counting the annual rings on the stump.

To evaluate the effect of tree statute on its crown architecture a sample of 96 trees was used. In each of the studied plots this sample corresponds to the selection of one tree per statute.

The statutes considered were the dominated one (***d***), represented by one tree included in the inferior diameter class, the medium one (***m***), represented by one tree with dbh similar to the sample mean diameter, and the dominant one (***D***), represented by one tree of the superior diameter class. Diameter class amplitude was 1cm.

For each tree, the following variables were measured: first dead branch height (1), first live whorl height (2), and total height (3). Evaluation 1 corresponds to the main stem depth - **msd**, the difference between 2 and 1 corresponds to the dead crown depth - **dcd**, and the difference between 3 and 2 corresponds to the live crown depth - **lcd**.

Analysis of variance (fixed effects ANOVA) and regression analysis were used for the statistical procedure. Modelling process consists of the establishment of several multiple analytic relationships among the architectural variables, those of provenance, statute, spacing and age, and dbh. Stepwise and ridge regression methods (backward and forward) were used to decrease the high correlation observed between some variables.

Crown architecture

The presence of crown, or its vestiges, along the stem is naturally linked to tree age and the spacing to which it was submitted during its life in stand. However, these vestiges are also related to thinning and pruning, and dependent of the progressive statutes the tree assume in the stand, systematically low thinned.

An analysis of lcd mean values allows us to verify that its oscillation is not significant in the whole sample; however, there is a sensible increasing tendency of these values with tree statute, *i.e.* from dominated to dominant trees (Figure 1).

The variable **dcd** increases with tree age, but the differences for each age are small with the changing of statute.

Obviously, **msd** increases with age in the whole sample. Nevertheless, for each considered age, this component of tree profile increases its from ***d*** to ***m*** trees, and decreases to ***D*** ones.

Generally, tree profile depths variability decreases with age; naturally, thinning induces stand homogeneity. Figure 2 shows that ***d*** trees statute present higher variability; the variable **lcd** performs the lowest variability, while **dcd** performs the highest.

About relative crown depth sizes, for each considered age there are no significant differences concerning the relative importance of the profile depths with the changing of tree statute (Table 1). At 10 and 15 years old, on one side, and 30, 50 and 70, on the other side (20 years old is the transition age), the weight of **lcd** in tree profile is transferred to the other components, which means that this variable decreases its relative importance in benefit of the other profile components.

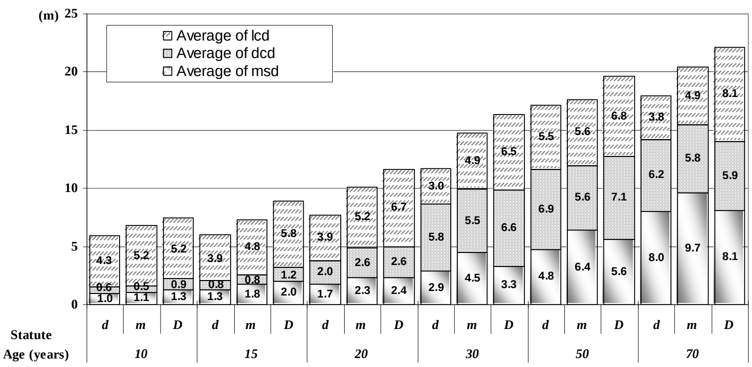

Figure 1 - Tree profile depths variation with age and statute

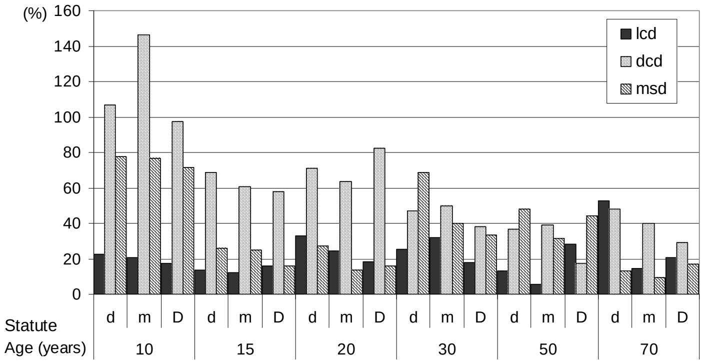

Figure 2 - Variation coefficient (%) of tree profile depths

Table 1 – Relative crown depth (compared with tree total height)

Age (years)	**10**			**15**			**20**			**30**			**50**			**70**		
Statute	***d***	***m***	***D***	***d***	***m***	***D***	***d***	***m***	***D***	***d***	***m***	***D***	***d***	***m***	***D***	***d***	***m***	***D***
lcd	0.7	0.8	0.7	0.7	0.7	0.6	0.5	0.5	0.6	0.3	0.3	0.4	0.3	0.3	0.3	0.2	0.2	0.4
dcd	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.2	0.5	0.4	0.4	0.4	0.3	0.4	0.3	0.3	0.3
msd	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.4	0.3	0.4	0.5	0.4

To analyse the effect of provenance on crown architecture, crown depth variables were studied using age, tree statute and the tree provenance as variability factors.
Table 2 shows the effect of the three considered factors and its possible interactions towards **lcd** significance. Inferences can be found in growth and presence of sound knots.
Tree statute is the most important cause of **lcd** variability. However, its influence on the evolution of this variable with age is diverse: while for ***d*** and ***m*** trees there are no significant changes in **lcd,** on ***D*** trees a visible increment of this variable can be noticed with age (Figure 3); this may be induced by the progressively growing difference of these trees, compared with those of the lower statutes.

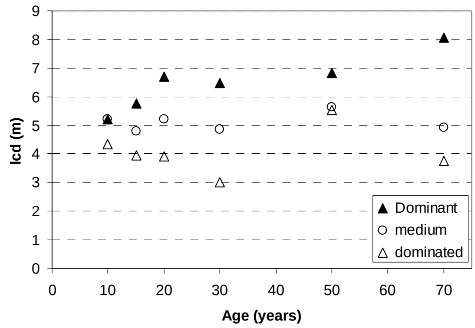

Figure 3 - Evolution of mean ***lcd*** with tree age and statute

The ***d*** and ***m*** trees usually show live crowns smaller than ***D*** ones, because they naturally have their crowns more shady then the latter.

There are no changes of **dcd** with tree statute; the variable is dependent on provenance and age factors (Table 3).

Table 2 - ANOVA of **lcd**

Effect	d.f. Effect	M.S. Effect	d.f. Error	M.S. Error	F	p
Provenance(1)	2	0.759	42	0.908	0.837	0.440
Age (2)	**5**	**3.258**	**42**	**0.908**	**3.588**	**0.009**
Statute (3)	**2**	**47.531**	**42**	**0.908**	**52.344**	**3.9E-12**
1×2	**10**	**3.084**	**42**	**0.908**	**3.396**	**0.003**
1×3	4	2.004	42	0.908	2.207	0.085
2×3	10	2.915	42	0.908	3.210	0.004
1×2×3	20	1.299	42	0.908	1.430	0.162

Table 3 – ANOVA of **dcd**

Effect	d.f. Effect	M.S. Effect	d.f. Error	M.S. Error	F	p
Provenance (1)	**2**	**25.972**	**42**	**2.032**	**12.781**	**0.000**
Age (2)	**5**	**120.663**	**42**	**2.032**	**59.379**	**0.000**
Statute (3)	2	2.435	42	2.032	1.198	0.312
1×2	**10**	**9.599**	**42**	**2.032**	**4.724**	**0.000**
1×3	4	1.233	42	2.032	0.607	0.660
2×3	10	0.828	42	2.032	0.408	0.935
1×2×3	20	0.854	42	2.032	0.420	0.980

This independence of **dcd** in what relates to tree statute suggests the existence of one level in the arboreal stratum, below which the reduced light intensity does not allow the occurrence of live branches.

The typical deficient maritime pine natural pruning will explain the increase of **dcd** with age. The inflexion observed for LNF and CNF in the evolution of this variable after the 30 years old of the trees (Figure 4) will be the natural reflection of a traditional silviculture, which uses the mean spacing between trees.

Concerning msd, significant differentces can be found for the different dominance statutes and the age factor (Table 4).

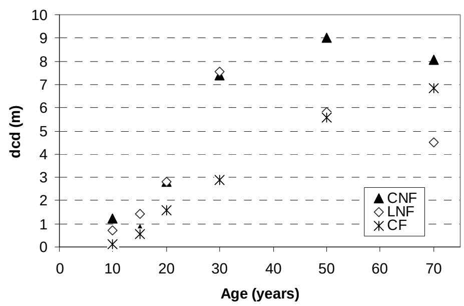

Figure 4 - Evolution of mean dcd by site with tree age

Table 4 – ANOVA for msd

Effect	d.f. Effect	M.S. Effect	d.f. Error	M.S. Error	F	p
Provenance(1)	2	1.240	42	1.313	0.944	0.397
Age (2)	**5**	**102.775**	**42**	**1.313**	**78.247**	**0.000**
Statute (3)	**2**	**8.642**	**42**	**1.313**	**6.580**	**0.003**
1×2	**10**	**4.406**	**42**	**1.313**	**3.355**	**0.003**
1×3	4	0.730	42	1.313	0.556	0.696
2×3	10	1.251	42	1.313	0.952	0.497
1×2×3	20	0.606	42	1.313	0.461	0.968

Naturally, the value of this variable increases with age; curiously, it happens almost exponentially until the tree maximum age (Figure 5). Referring to the effect of the statute factor on the variable, significant statistic differences were only found when ***d*** trees were compared with ***m*** ones (Table 5). However, in the oldest stands, ***m*** trees present longer **msd** than ***D*** trees, which may be explained by their smaller vigour, and consequently, the smaller persistence of dead branches.

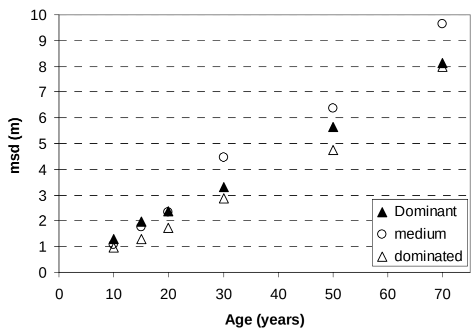

Figure 5 - Evolution of mean ***msd*** with tree age and statute

Table 5 – Homogeneous groups for **msd** grouped by statute (LSD test, α = 0.05)

	Group 1	Group 2
d	xxxx	
D	xxxx	XXXX
m		XXXX

Tree profile models

The following models were selected for each of the architectural variables, based on the correlation level found in the regression analysis variance, and on its accuracy and skewness:

(1) **lcd** (m) = $- 0.004*t^2 + 0.0007*sp*t^2 + 0.011*dbh^2 - 0.0015*sp*dbh^2 + 4.37$

As observed in ANOVA analysis, there is no contribution of the provenance variables to the establishment of **lcd** model. On the contrary, tree statute, which does not integrate the model, integrated its effect by dbh; this one is the most relevant variable inside this model.

(2) **dcd** (m) = $- 2.58*CF - 0.86*LNF + 1.034*sp + 3.48*\ln t + 0.056*dbh - 3.5*10^{-5}*sp^2*t^2 - 10.32$

Concerning this model, it is at CNF (the northern forest) where trees present longer **dcd** ($\beta_{CNF}=0$).

The model does not integrate the tree statute but it is strongly influenced by spacing; the deficient maritime pine natural pruning, eventually stimulated by large spacing inducing longer **dcd,** may explain this fact.

No significant influence of tree statute in **dcd** is registered.

(3) **msd** (m) = 0.55*CF - 1.58**D* + + 0.0011*t^2 - 2.52*ln sp + 1.83*ln dbh +0.013*sp*dbh - 0.73

Model 3 shows that pines of CF (the southern forest) have in average an **msd** 0.55m higher than those of the other two forests.

This is the only model that integrates one variable related to tree statute in the stand. The ***D*** trees apparently have a main stem 1.58m smaller than those of ***d*** and ***m*** ones; however, this trend will be contradicted by the positive influence of dbh inside the model.

According to model 3, larger spacing between trees induces shorter lengths of stems without branches, which means shorter **msd**.

An analysis of the three models presents **lcd** as the biometric variable less dependent on mean spacing. The dependent variable **dcd** is the more influenced by the provenance variables. The variable **msd** is the only one where tree statute has direct influence in its value.

In terms of *adjusted* R^2, it is the **msd** regression curve that shows the better adjustment to the dispersion diagram (Table 6). The small values obtained for p-level allow us to say that each of the three models can explain most of the phenomena.

The residual analysis leads us to conclude that both the skewness (expressed by the deleted residual mean) and the precision (expressed by the absolute deleted residual mean) are satisfactory in any of the three models.

Conclusions

The following main conclusions can be taken from this study:

- The size of live crown increases with tree statute in the stand. However, for one particular age and independently from tree statute, the lower canopy level stays constant as the result of identical levels reached by the sum of depths of the lower components of tree profile.

- For a given age, tree statute in the stand seems not to underline significant differences in the magnitude of dead crown depth.

- Main stem depths get the highest values in the medium trees; the dominant ones present the lowest values; these are identical to the main stem depths of the dominated trees.

- Live crown depth is independent of provenance and hierarchic factors, and slightly dependent on mean tree spacing; however, it is very influenced by dbh. Trees with larger dbh naturally present longer live crown depths.

Table 6 – Statistics of the models

Model	**adjusted R^2**	**p-level**	**deleted residual mean**	**absolute deleted residual mean**
lcd	0.61	1.07×10^{-18}	-0.003	0.83
dcd	0.77	1.34×10^{-27}	0.007	1.11
msd	0.86	1.31×10^{-37}	0.001	0.78

- In the northern littoral region, the most productive one, the trees present the bigger crown depths, particularly dead crown. Dead crown depth is highly influenced by mean tree spacing. This aspect underlines the particular importance of the space management processes in the acquisition of stems without dead crown and parts of dead branches; all these facts have obvious implications on the production of high quality wood raw material.

- Dominant trees show a tendency to present smaller main stem depths than the others. Provided that these trees constitute most of the individuals that reach the end of the productive cycle inside the stand, it is fundamental that they have been artificially or naturally pruned.

- Artificial pruning, in particular of live crown, must be very well planned in time, and applied as high as possible on the basal log. By this way, the valorisation of a long commercial stem can be promoted, from which, lumber with just a few small knots and with a limited proportion of loose knots can be obtained.

Acknowledgements

Thanks are due to all the colleagues working on littoral forests and at the National Forest Research Station, by their aid during data collection and preparation, and to PAMAF-IED 8185 Research Project, for the financial support. Special thanks to written English correction by our friend Inês Portugal.

References

AMARASEKARA, H., DENNE, M.P., 2002. Effects of crown size on wood characteristics of Corsican pine in relation to definitions of juvenile wood, crown formed wood and core wood. *Forestry* **75**(1) : 51-61

CAMERON, A.D., 2002. Importance of early selective thinning in the development of long-term stand stability and improved log quality: a review. *Forestry* **75** (1) : 25-35.

MÁTYÁS, C., VARGA, G., 2000. Effect of intra-specific competition on tree architecture and above ground dry matter allocation in scots pine. *Invest. Agr.: Sist. Recur. For.: Fuera de Serie* n.º 1-2000: 111-119.

TAVARES, M., 1989. *O pinhal bravo das dunas do litoral entre Douro e Mondego. Produção lenhosa e crescimento do sistema radical*. Dissertação original. Ex-INIA - EFN, Lisboa.

TAVARES, M., 1999. Maritime pine wood quality in Portugal. A few reasons responsible for some of its characteristics and defects. In *2nd Workshop of COST action E10 - Wood properties for industrial use*, 7 pp. Tapada de Mafra, Portugal, 13-15 June.

ZOBEL, B.J., BUIJTENEN, J.P., 1989. *Wood variation. Its causes and control*. Springer--Verlag. London.

Entregue para publicação em Abril de 2001
Aceite para publicação em Julho de 2003