

QUALITY GRADING OF WOODEN POLES PRODUCED BY SCOTS PINE (*PINUS SYLVESTRIS* L.) FORESTS IN WEST RODOPI (N. GREECE)

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ABSTRACT

Trunks of Scots pine (*Pinus sylvestris* L.) are widely used for poles in power transmission and telecommunication lines. The objective of this work was to apply visual quality indexes on wooden poles, based on basic wood defects. Poles were characterized according to various defects and geometric characteristics, namely: knots, spiral grain, sweep, taper, rate of growth and dimensions. Poles that did not meet the established minimum requirements of the standards applied by the public power corporation, were rejected. The results showed that from the 82 trees investigated a high percentage (90.2%) met the standards and were suitable as power transmission poles.

Key words: Scots pine, poles, defects, visual grading.

1. INTRODUCTION

Scots pine (*Pinus sylvestris* L.) is the most widely distributed conifer species in the world with a natural range stretching from Spain to Norway, and from Scotland to Siberia (Mason 2000). Natural forests or plantations of this species are found in most member states of the EU (Mason and Alia 2000). It is a commercially important tree species in Europe, since its wood is easily workable, with good mechanical properties, and has many uses, primarily as construction timber and pulpwood (Mátyás *et al.* 2004).

In Greece, Scots pine is limited to specific areas. Pure and mixed stands of Scots pine (*Pinus sylvestris* L.) occupy an area of 20.944 ha (National Inventory of Forests 1992). As a high altitude species, Scots pine usually forms the tree line in the Greek mountain ranges of Pieria, Vermio, Orvilos, Lailias and Rhodope which constitute the species' Southernmost limits of European distribution (Grigoriadis *et al.* 2014).

Wooden poles are made from debarked round wood and treated by using vacu-

um/pressure impregnation methods with preservatives, in order to be used in direct contact with the ground or water. This treatment provides resistance to the attack of biological agents and ensures that the poles are totally protected, resulting in a reliable, long lasting product with greater durability.

Scots pine timber can be readily impregnated with preservative and is therefore widely used for poles in power transmission and telecommunication lines. Such poles are specially selected for their shape and straightness (Gjerdrum and Salin 2009).

Quality grading of forest products and particularly of roundwood is of great importance to the timber market, since it specifies the usage, constitutes the base for trading and finally influences greatly the market prices. Standards are applied for the quality classification of roundwood. European countries apply their national standards or European standards where they exist (Tsoumis 1991, Voulgaridis 2002). Pole prices can be substantially higher than saw log prices, especially when selling longer poles. The species, size and class of a pole

determine its price. Each pole has a minimum top diameter and a minimum circumference. Pole prices are depended on the

length and the diameters of the base and the top of the poles (Oester and Bowers 2003).

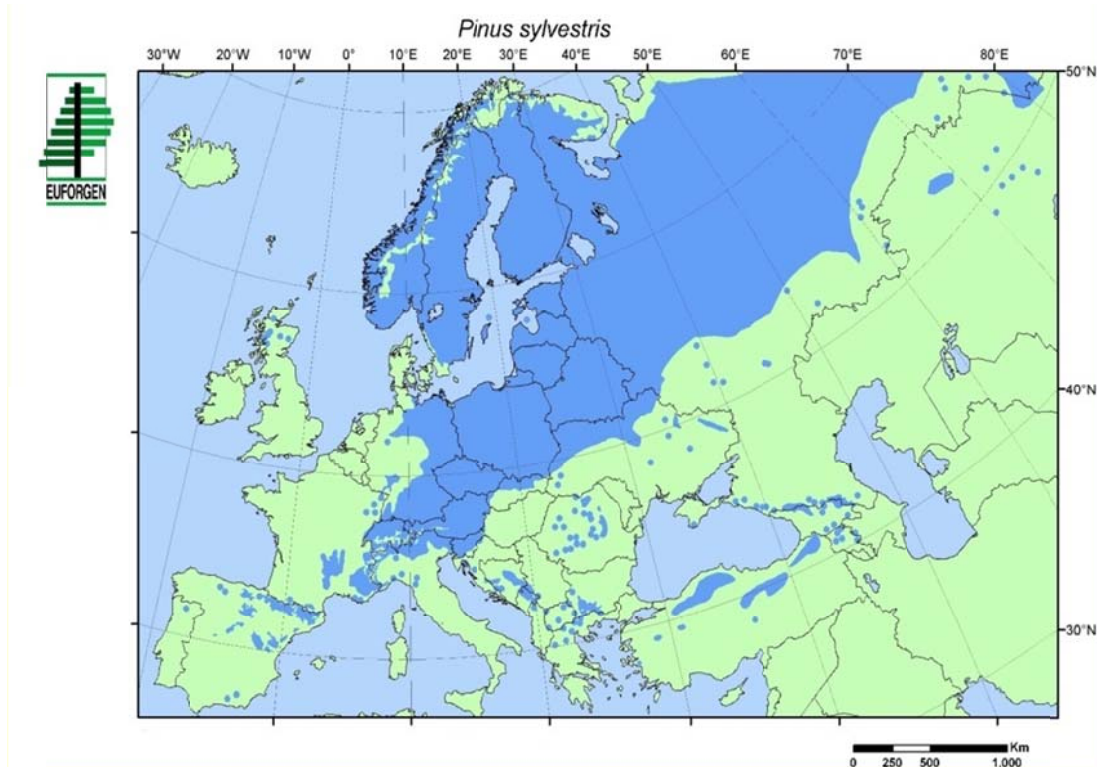


Figure 1: The natural distribution area of Scots pine (*Pinus sylvestris*) in Europe (EUFORGEN 2009).

Quality classification of wooden poles in state forests in Greece is based on visual appearance of logs and their dimensions (length and diameter). The GR-49 specification by the Public Power Corporation (P.P.C.), issued by the standardization department, covers the production and treatment of wooden poles. Poles that did not meet the established minimum requirements of the standards and directives applied by the P.P.C., are rejected (GR-49 1981, Voulgaridis 2002).

In the present investigation, a qualitative and quantitative evaluation of wooden poles produced by Scots pine (*Pinus sylvestris* L) forests has been carried out in West Rodopi (N. Greece). The objective of this work was to apply visual quality index-

es on poles production, based on basic wood defects and typical minimum characteristic values for wood poles.

2. EXPERIMENTAL METHODS

2.1. EXPERIMENTAL FOREST STANDS

As experimental area, the stands numbered 63ε and 63ζ in the “Vathyrema” region at the “West Nestos” forest complex of Drama prefecture, North Greece, were selected according to the forest management plan. These two forest sites are characterized by similar stand conditions (see Fig. 2). General information of the stands selected and the number of the investigated Scots pine trees are shown in Table 1.

Table 1: General information of forest stands and number of trees investigated.

Stand	Area [Ha]	Elevation [m]	Orientation	Slope [%]	Tree species	Number of Trees	Range of diameter at breast height [cm]
63ε	66.00	1450–1520	S–SE–SW	20–50	Scots pine	42	27.5 – 42.5
63 ε	42.50	1450–1520	S–SE	20–50	Scots pine	40	25.5 – 40.0
Total trees investigated / Range of breast height diameters						82	25.5 – 42.5

Totally 82 marked Scots pine trees, which were scheduled to be cut and logged, were investigated. The breast height diameter of the trees ranged between 25.5 and

42,5 cm (Table 1). From these trees, 82 power transmission poles were produced.

**Figure 2: View of the investigated stands at the “Vathyrema” forest region of Drama prefecture.**

2.2 VISUAL GRADING OF POLES

The poles were inspected on all their sides, and all features were checked, recognized, classified and measured. The dimensions, volume, rate of growth and defects (number and size of knots, spiral grain, taper, sweep, ovality, fissures, compression

wood) of each pole were recorded in detail on special forms (EN 1309-2 2005, GR-49 1981, Voulgaridis 2002, Morgado *et al.* 2008, Morgado *et al.* 2010). Based on the GR-49 specification the cut poles shall conform to the following requirements of length and diameter as shown in Table 2.

Table 2: Categories and required dimensions of poles according to GR-49 1981.

Length (m)	Minimum diameter at 1,80 m from butt		
	Heavy (cm)	Medium (cm)	Light (cm)
9	26	22.5	19
10	27	23.5	20
11	28	24.5	21
12	29	25.5	22
13	30	26.5	23
14	31	27.5	24
15	32	28.5	25
All lengths	Minimum diameter at top		
	18 cm	15 cm	12 cm

The following defects are permitted for power transmission poles according to GR-49 1981:

Knots are permitted provided the diameter of any single knot does not exceed 8 cm, and the sum of the diameters of all knots exceeding 1.2 cm diameter in any 30 cm of length of pole does not exceed 20 cm. Spiral grain is permitted to the limit of half a turn in any 3 m length for poles 9 m long, half a turn in any 5 m length for poles 10 to 14 m long and half a turn in any 6 m length for poles 15 m long. Furthermore, the outer 2.5 cm of all poles shall be free from compression wood visible on either end.

Checks consisting of separation of the wood along the grain in a radial direction, are permitted in the butt provided that they are not more than three and they do not extend more than 60 cm above the butt end. Shakes consisting of separation along the grain in tangential direction, the greater part of which occurs between the rings of annual growth, are permitted in the butt surface,

provided that they do not extend longer than 1.5 m from the butt end.

The average rate of growth, measured on the butt and along any radius, in the outer 5 cm of poles having a circumference of 95 cm or less at 1,80 m from the butt, and in the outer 7.6 cm of poles having a circumference of more than 95 cm at 1.80 m from the butt, shall be not less than 2.3 rings per cm.

Poles shall be straight and free from crooks or localized deviations from straightness which, within any section 2 m or less in length, are more than one-third of the mean diameter of the crooked section. Poles may have a single sweep or curvature in one direction provided that a straight line joining (1) the surface of the pole at a distance of 1,5 m from the butt and (2) the edge of the pole at the top, shall not be distant from the surface of the pole at any point more than 8 mm per meter of length between points (1) and (2) (See Fig. 3).



Figure 3: Measurement of sweep in one plane and one direction (GR-49 1981).

Poles may have a double sweep or curvature in two planes or reverse sweep (curvature in two directions in one plane), provided that a straight line joining (1) the mid-

point at a distance of 1,5 m from the butt and (2) the mid-point at the top, does not approach the surface of the pole closer than 20 mm (See Fig. 4).

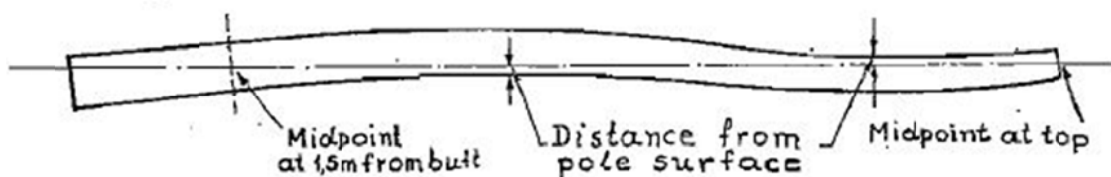


Figure 4: Measurement of sweep in two planes (Double sweep) or in two directions in one plane (GR-49 1981).

3. RESULTS AND DISCUSSION

The results are shown in Tables 3-4 and Fig. 5. Scots pine trees were cut and converted to (produced) 82 poles, ranging from 10 to 15 m in length. All the poles fulfilled the standard minimum limits of length, of diameter at 1.80 m from the butt and of di-

ameter at the top. Based on the requirements of the P.P.C. specifications, a high percentage of 85% (70 poles) of the total produced poles were characterized as “Heavy” and the rest 15% (12 poles) were indicated as “Medium”, as shown in Table 3.

Table 3: Classification of the produced poles into categories based on minimum dimensions required according to GR-49 1981.

Categories	Dimensions			Number of poles
	Length [m]	Minimum diameter at 1,80 from the butt [cm]	Minimum diameter at the top [cm]	
Heavy	10.0	28.0	20.5	2
	11.0	31.5	19.0	3
	12.0	32.5	19.0	7
	13.0	32.0	20.0	16
	14.0	32.5	19.5	33
	15.0	34.0	22.0	9
Medium	10.0	24.0	18.5	2
	11.0	25.5	19.0	2
	12.0	27.0	19.0	1
	13.0	27.5	19.0	5
	14.0	30.0	18.5	2
Total				82

A key visual parameter is the presence, number and size of knots because of the deviation they cause in the longitudinal fibers (Martins and Dias 2012) and the reduction in mechanical strength of wood. For this reason, special attention was paid to this feature. This was accomplished by measuring the number and the diameter of single knots. From these measurements two parameters were determined: the maximum diameter of a single knot in any pole and the maximum sum of all the knot diameters in any 30 cm of length of pole. Knots appeared to be present in all poles ranging in diameter from 1.5 cm to 8.0 cm. The sum of the diameters of all knots exceeding 1.2 cm diameter in any 30 cm of length of pole ranged from 3.0 to 16.0 cm. The results showed that all the poles fulfilled the requirements for the presence of knots.

The spiral grain was assessed by taking a line parallel to the surface checks and measuring the inclination of the checks relatively to the longitudinal axis of the log (EN 14229 2010, Morgado *et al.* 2008). The spiral grain was observed in 37 pole logs, a percentage 45% from the total poles produced and it ranged from 3 to 11 cm in any 1 m of length of pole. From the 37 pole logs, a great number (84%) showed a spiral grain equal or lower than 8.0 cm/m, the limit value established according to P.P.C specifications. In total, a percentage of 92.5% of the poles’ production met the standards for the presence of spiral grain.

Most of the poles (90%) were straight and free from localized deviations from straightness. A percentage 4% of the poles showed single sweeps, while the rest 6%

had double and reverse sweeps and were rejected.

The taper was assessed based on the mean diameter (mean of maximum and minimum diameter) measured in sections at least 5 cm from the ends, and the distance between those sections. The taper was then considered as the difference between the two mean diameters divided by the distance between the measuring points (Morgado *et al.* 2008). The gradual reduction in diameter along the length was found to be low, ranging from 4.5 to 8.0 mm/m and it was not taken into account in the application of the GR-49 standard. As for the presence of compression wood, poles fulfilled the requirements of P.P.C., as all the logs showed wood free from compression wood in the outer 25 mm, on either ends.

The ovality, when significant, can compromise the practical use of the log, both because of the shape and of the amount of compression wood present. This feature was assessed by measuring the maximum and the minimum diameters in a section located at least 1m away from the larger end (Morgado *et al.* 2008). The ovality was given by the difference between the maximum and minimum diameter of a cross section, expressed as a percentage of the minimum diameter (EN 14229 2010). Ovality was present in poles to a small degree, ranging

from 3.7% to 5.2%, thus it was not considered for the P.P.C. requirements.

In all poles, checks were found to be not more than two and to an extent less than 60 cm from the butt. Shakes were not observed in the butt end of poles. The results obtained for the presence of checks and shakes followed the requirements for pole's production given in GR-49 specification.

The rate of growth is a very important parameter for softwoods, since it reflects, in an indirect way, the density of the wood, which has a significant influence on the strength and stiffness of timber members (Morgado *et al.*2008). In practice this feature was determined by measuring the size and the number of growth rings in the outer 5 cm of poles. The rate of growth suggested by the GR-49 standard shall not be less than 2.3 rings per cm. All the produced poles fulfilled this condition, as the average rate of growth ranged from 3.1 to 4.8 rings per cm.

Based on the presence of the above mentioned visual quality indexes, 82 produced poles were classified into two categories: i) as permitted were characterized the poles that met the standards applied by the P.P.C., and ii) as rejected were indicated the poles that did not meet the established minimum requirements of the standards. The results of the classification of the produced poles based on the presence of the quality indexes, are presented in Table 4.

Table 4: Classification of the produced poles, based on the presence of the quality indexes.

Quality indexes	Poles					
	Permitted			Rejected		
	Degree of defect	Number of poles	% of total production	Degree of defect	Number of poles	% of total production
Dimensions		82	100		0	0
Knots	a. diameter (D) < 8 cm					
	b. sum of D in 30 cm < 20 cm	82	100		0	0
Spiral grain	≤ 8 cm/m	76	92.5	> 8 cm/m	6	7.5
Sweep	a. single ≤ 8 mm/m	77	94,0	a. single > 8 mm/m	5	6

Quality indexes	Poles					
	Permitted			Rejected		
	Degree of defect	Number of poles	% of total production	Degree of defect	Number of poles	% of total production
	b. double ≥ 20 mm/m			b. double < 20 mm/m		
Taper	low	82	100		0	0
Compression wood	free in outer sapwood 25 mm thick	82	100		0	0
Ovality	low	82	100		0	0
Checks (radial)	a. $<$ than 3	82	100		0	0
	b. extended $<$ than 60 cm from the butt					
Shakes (tangential)	extended $<$ than 1,5 m from the butt	82	100		0	0
Rate of growth	$\geq 2,3$ rings / cm	82	100		0	0
Total		74	90.25		8	9.75

From the results presented in Table 4, it becomes clear that a high percentage (90.25%) of the produced Scots pine poles met the standards and were suitable as power transmission poles. Furthermore, it was

found that a small percentage (9.75%) of the poles did not fulfill the minimum requirements of the standards applied by the P.P.C. and were rejected.



Figure 5: Produced poles that met the requirements of the P.P.C. standard.

4. CONCLUSIONS

In this study, the quality evaluation of wood poles produced by Scots pine (*Pinus sylvestris* L) forests in West Rodopi (N. Greece) was investigated.

The results obtained here clearly show that Scots pine forests exhibit a potential for production of power transmission poles. The applied visual quality indexes, indicated that from the 82 trees investigated a high percentage 90.25% (74 poles) of the total 82 produced poles fulfilled the minimum requirements specified by the P.P.C. and were

classified as permitted for the application in utility poles.

The results clearly indicate that the most common grading process, namely the application of visual quality indexes, based on basic wood defects, can be used with success for Scots pine pole's production. The results derived from this study contribute to a better understanding of the influencing wood defects on the pole production of Scots pine forests.

However, it is possible to improve the existing grading procedures. The application

of new methods, like ultrasonic timber grading systems or grading of logs with an X-ray log scanner is expected to help in better quality classification of the power transmission poles and to increase the percentages of the production of suitable poles' of better quality.

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