Natural Durability of Narrow Leaved Ash (*Fraxinus angustifolia* Vahl.) Wood from Planted and Natural Stands

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Abstract

Sustainability of natural forests is under pressure due to some social and economic problems existing in developing countries. In such countries, creation of new resources for wood production by plantation establishment is necessary in order to protect forest eco-system and to meet the demand for wood. Fast-growing plantations will be relied upon as a key element in meeting future demand for wood. *Fraxinus angustifolia* Vahl. (Narrow leaved ash-NLA) tree is the most important species for Turkey because of its fast growing ability and valuable wood. It is also used in parquet, sports tools, mine poles, and caique building. The exceptional property of ash is its bending ability and flexibility. NLA wood is known as non-resistant to fungi but there is no information about planted ash wood. For this reason, possible durability differences between planted and natural grown NLA wood was studied in this study.

Natural durability of fast growing NLA species, grown in plantation and natural stands was evaluated by soil-block decay test method according to ASTM D- 2017 -05. The ash trees were felled down from Adapazarı and Sinop regions and then test specimens were exposed to a brown rot fungus *Gloeophyllum trabeum*, two white rot fungi *Pleurotus ostreatus* and *Coriolus versicolor* for 12 weeks. The natural durability was determined by the weight loss percentage of the test blocks.

As a result, there is no significant different between plantation and natural grown NLA wood durability against brown and white rot fungi. Tests showed that *P. ostreatus* resulted in heigher weight loss than the other test fungi and there was no change on durability classes.

Keywords: Plantation, Natural durability, Narrow-leaved ash, Fast growing species.

Plantasyonda ve Doğal Meşcerelerde Yetişen Dar Yapraklı Dişbudak (*Fraxinus angustifolia* Vahl.) Odununun Doğal Dayanıklılığı

Özet

Doğal ormanların sürdürülebilirliği, gelişen ülkelerde bazı sosyal ve ekonomik nedenler ile baskı altındadır. Bu gibi ülkelerde orman eko sistemini korumak ve odun ihtiyacını karşılamak için plantasyon sahaları kurularak odun tüketimi için yeni kaynakların oluşturulması gerekmektedir. Hızlı gelişen plantasyonlar gelecekte odun talebini karşılamada anahtar eleman olarak görülmektedir. *Fraxinus angustifolia* Vahl. (Dar yapraklı dişbudak-DYD) ağaçları hızlı büyüme yeteneği ve değerli odunundan dolayı Türkiye için en önemli türlerdendir. Parke, spor aletleri, maden direkleri ve kayık üretiminde kullanılmaktadır. DYD odunu mantarlara karşı dayanıksız olarak bilinmektedir fakat plantasyonu yapılmış dişbudak odununun dayanıklılığı hakkında herhangibir bilgi bulunmamaktadır. Bu nedenle, mevcut çalışmada plantasyonda ve doğal yetişen dar yapraklı dişbudak odunlarının olası dayanıklılık farklılıkları çalışılmıştır.

Plantasyonda ve doğal meşcerelerde hızlı yetişen *Fraxinus angustifolia* (Vahl.) odununun ASTM D 2017 05 standardına göre odun çürüten mantarlara karşı doğal dayanıklıkları belirlenmiştir. Adapazarı ve Sinop bölgesinden ağaçlar kesilmiş ve test örnekleri bir esmer çürüklük mantarı (*Gloeophyllum trabeum*) ve iki beyaz çürüklük mantarına (*Pleurotus ostreatus* ve *Coriolus versicolor*)12 hafta ile maruz bırakılmıştır. Doğal dayanıklılık test bloklarındaki ağırlık kaybı yüzdesi olarak belirlenmiştir.

Sonuç olarak plantasyonda ve doğal olarak yetişen dar yapraklı dişbudak odunlarının beyaz ve esmer çürüklük mantarlarına karşı doğal dayanıklılık bakımından istatistikî olarak anlamlı bir farklılık bulunmamıştır. Denemeler *P. ostreatus* mantarının diğer mantarlardan daha fazla ağırlık kaybı göstemesi ile sonuçlanmıştır ve dayanıklılık sınıfında değişim olmamıştır.

Anahtar Kelimeler: Plantasyon, Doğal dayanıklılık, Dar yapraklı dişbudak, Hızlı yetişen türler.

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Introduction

Fast growing species have been introduced to Turkey since 1880's. The earliest one was maritime pine (*Pinus pinaster)* and it was followed by river red gum (*Eucalyptus camaldulensis*) in 1939. In 1950's, there have been demonstrative plantations and comperative experiments of exotic coniferous species at various levels conducted by several different organizations (Ayan and Sivacioglu, 2006). One of the important fast growing hardwood species is *Fraxinus angustifolia* (Vahl.) (Narrow leaved Ash) for Turkey. In Turkey, almost all ash forest areas are covered by *F. angustifolia* (about 12,000 ha) as opposed to the other native ash species (*F. excelsior* and *F. ornus*) (Anonymous, 2001). NLA tree is a fast-growing species with a rotation age of 40 years (Cicek and Yilmaz, 2002). The mean annual increment can reach about 25 m^3 ha^{-1} and 15 m^3 ha^{-1} of stem wood over bark without any additional fertilizers or irrigation in plantations and natural stands, respectively; current annual increments can reach 33 m^3 ha^{-1} of stem wood over bark at 15–20 years (Kapucu et al., 1999).

F. angustifolia yields high quality white wood and is preferred in the veneer and furniture industry. *F. angustifolia* wood characteristics show similarities to *F. excelsior* (Fraxigen, 2005). It is also used in parquet, sports tools, mine poles, and caique building. The exceptional property of ash is its bending ability and flexibility after seasoning, which makes it very suitable for sport goods and handles of tools such as sledgehammers (Gürsu, 1971; Bozkurt, 1971) *F. angustifolia* is widely used in landscaping as well as in industrial plantations. Despite NLA relative importance, little is known about wood structure, physical-mechanical properties, durability, chemistry which grown in plantation stands.

Wood being a biological material is liable to be destroyed by various destroying agencies which degrade wood single or in combination, insects and termites consume the entire wood substances while different fungii attack different components of wood (Indra Dev et al., 2001). Several factors effects wood durability against fungi such as extractive content and type, lignin content and type, tree type, nitrogen content, physical properties including density, anatomical structure, locality, tree size and position, heartwood and sapwood deistribution, conditions of use (Panshin and de Zeew, 1980; Yamamoto and Hong, 1994; Suttie and Orsler, 1996; Antwie-Boasiako, 2004; Antwie Boasiako and Pitman, 2009; Olfat, 2011). Natural durability is a factor that varies enormously in any given sipecies, not only between trees, but also within the same tree (Baillĕres and Durand, 2000). It is therefore difficult to state with any certainty how durable a wood is for a particular species, as this durability depends on several factors, including the genetic origin of the tree, silviculture, climate, and the local environment. Therefore, in order to judge the quality of ash wood originating from different sites in Turkey where little information exists concerning wood quality of plantation grown ash, it is necessary to classify wood. The service-life of wood products may depend primarily on their durability, a relevant factor, which contributes in reducing the rate of wood exploitation and replacement thereby increasing its sustainability (Kollman and Côté, 1984). Wood selection from durable or preservative-treated, non-durable timber is influenced by cost, end-use, required shape and size (i.e. its dimension). Therefore, knowledge of wood durability is important because it enables planning for the service life of the wood products (Antwi-Boasiako and Allotey, 2010).

Because of planted trees are young, the trunks consist entirely of juvenile wood and the proportion of sapwood if therefore high. According to the authors the durability of teak is not however determined by the total amount of extractives but by the content of naftoquinone. It is also reported that the durability of teak is related to the position of the wood in the trunk. The central parts near the pith have lower durability (Thulasidas and Bhat, 2006; Kokutse et al., 2006). Teak wood in Costa Rica showed the same durability class. The heartwood of plantation teak timber therefore expectations regarding its durability (Wolfsmayr et al., 2008).

A characteristic feature of the plantation teak is that the trees are harvested at a very early stage. This knowledge however refers mainly to natural forest, i.e. older trees. The influence of tree age on the durability of timber is thus of considerable significance for the commercial interest of the company.

Planted trees are harvested at early ages so it effects the wood properties. Baht and Florence (2003) was evaluated the natural durability of different age class Teak wood which grown in plantation stands. According to results 5-year-old juvenile wood from high input plantations is less decay resistant than the wood of 13- year-old trees and mature teak wood of forest plantations. Timbers of four age groups5, 10, 15 and 20 years of two plantation grown sepecies of *Ailanthus excelsa* and *Ailanthus malabarica* were tested for their natural resistance against wood decay fungi in laboratory conditions. Both the *Ailanthus* species exposed to fungus showed that they belong to the same durability class (Venmalar et al., 2011).

Information on the resistance to insect and decay fungi is important to evaluate the utilization potential of any species, besides knowing the anatomical, physical and mechanical properties. Since service life can be based on natural durability classes, it is evident that these are identified differently for uses in or out of ground contact for softwood and hardwoods. Ash wood is not durable (class 5 according to standard EN 350-2, 1994) and the objective of the present study was therefore to study the differences between the natural durability of ash wood grown in planted and natural stands.

Material and Method

Narrow leaved ash trees were felled from two different sites in North of Turkey. Natural stands were belong to Akyazı region in Adapazarı (40º47’52” / 30º32’42”), and Bektaşağa in Sinop (42º00’22” / 34º55’39”), planted stands were belong to Hendek region in Adapazarı (40º51’51” / 30º34’58”) and Bektaşağa region in Sinop (41 º59’01” / 35º55’11”). All planted tress were taken from the same spacing stands (3x2m). The location and details of the three sites and sampled trees are given in Table 1. In Adapazarı planted and natural NLA trees are the same ages aproximately 30 years but in Sinop natural NLA trees (96-112 years) are older than the planted NLA trees (45 years).

Table 1. Site and narrow leaved ash trees characteristics.

Site	**Adapazarı (A)**		**Sinop (S)**	
	Nature	**Plantation**	**Nature**	**Plantation**
Tree age [a](years)	29-30-31	32-34	99-107-115	47-49
Region name/No	Çatalköprü/10	Süleymaniye/121	Başaran village/59	Başaran village/59
Altitude (m)	25		10	
Precipitation (mm yr^{-1})	783		670-1077	
Mean temperature (°C)	14.1		14	
Soil	Clay loam		Clay loam	
DBH (cm)	30-32	28,5-30-35	34-35	34-35
Tree height (m)	25-27	25-26	26-30	21-23
Number of rings at DBH	27-28-28	30	104-96-112	45

[a]: Measured by ring counting at the stem base.

Each region we felled down three trees, totally 12 trees. All wood samples were taken from 0.3 m of trunk and the outer sapwood portion was removed, and inner heartwood was sawn into 1.9x1.9x1.9 cm battens radially from the centre to the periphery of the heartwood cylinder, excluding pith, for preparing test blocks. The test blocks were made from clear heartwood and were free from knots, stain, decay, insect hole sor other deformity or defects.

The cubes were conditioned at 60 °C until they reached a constant weight, then weight their first record (W1).

The test fungi included one brown-rot fungi, *Gloeophyllum trabeum* (Pers. ex Fr.) Murr. Mad-617 (USDA Forest Service, Forest Products Laboratory, Madison) and two white-rot fungi, *Pleurotus ostreatus* (Jacq.: Fr.) P. Kumm. PLO 9669, *Coriolus versicolor* (L.: Fr.) Quél. COV 1030 (Kyoto University, Laboratory of Innovative Humano-habitability Research Institute for Substainable Humanosphere) were used in this study (Figure 1).

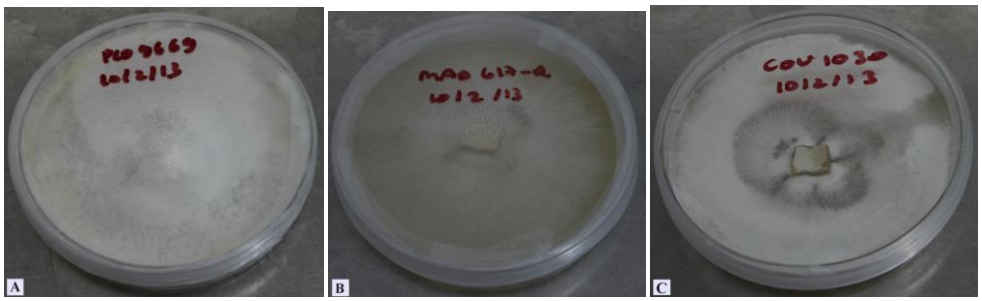

Figure 1. A) *Pleurotus ostreatus* (Jacq.: Fr.) P. Kumm. PLO 9669, (B) *Gloeophyllum trabeum* (Pers.:Fr.) Murrill Mad-617-R, (C) *Coriolus versicolor* (L.: Fr.) Quél. COV 1030.

The decay test was conducted according to ASTM D-2017-05 procedures (ASTM, 2005). Bottle was filled with horticultural soil. The soil was kept at 130 % of its water holding capacity (WHC). Beech and pine feeder strip measuring 3 × 29 × 35 mm was placed above the soil in each bottle and the bottles were autoclaved for one hour at 121 °C. The bottles were inoculated with agar plugs cut from the edge of an actively-growing colony of the test fungus. Culture bottles were incubated until the fungus covered the feeder strips. Bottles with vigorous fungus growth without contamination were selected for the soil block test (Figure 2).

Figure 2. Mycellium growth on feeder strip.

The inoculated jars were then incubated in a growth room at 25^{o}C and a relative humidity of 70% for 3 weeks for the mycelia of the fungus to completely colonize the wood strip. After 3 weeks incubation period, the wood blocks (19 mm x 19 mm x 19 mm) were sterilized at 121^{o}C at 1 atm for 20 minutes and placed transversely on the mycelial mats in the growth chambers. The glass jars were then incubated again for 12 weeks. After incubation, adhering mycelium was removed, fungal mycelium were carefully and gently brushed off from the blocks with a sponge and the blocks. Mycelium-free blocks were placed in the oven at 60±2 ºC for 3 days (Figure 3). The weight of the conditioned cubes after the12 week incubation period and the removal of the fungal mycelium (W2) using the following equation:

Weight loss, % = [(W1 – W2)/W1]x100

W1= Oven dry weight of wood prior to the decay test (g)
W2= Oven dry weight of wood after the decay tes (g)

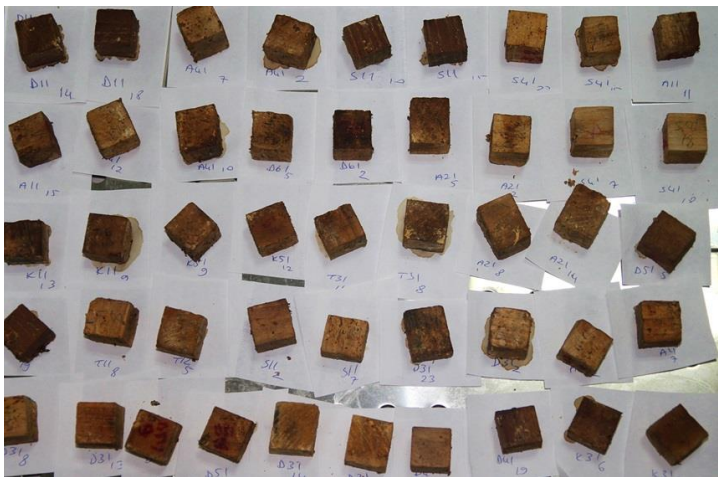

Figure 3. Test specimens after decay test.

Data from the accelerated decay test were analyzed for determining the performance of natural decay resistance using Analysis of Variance (ANOVA). The durability of ash was classified according to the norm ASTM D 2017-05 (ASTM, 2005). Table 2 shows the index classification.

Table 2. Durability classification according to ASTM D 2017-05.

Average Weight loss (%)	Average Residual Weight (%)	Classification
0 to 10	90 to 100	Highly resistant (Class I)
11 to 24	76 to 89	Resistant (Class II)
25 to 44	56 to 75	Moderately resistant (Class III)
45 or above	55 or less	Slightly resistant or nonresistant (Class IV)

Results and Discussion

The biological durability of wood is one of the most important properties of building material. The characterisation of this property is of great importance in appropriate material selection and real indicator for performance in service.

The average weight loss (%) and descriptive statistics of the total samples per fungus was calculated and the values are given in Table 3.

Table 3. Descriptive statistics of weight loss after 12 weeks exposure to brown and white rot fungi in NLA wood.

Fungi	Origin	Region	Specimen Number	Weight Loss (%)	Standard deviation	Min. Value(%)	Max. Value(%)
Gloeophyllum trabeum	**P**	Adapazarı	18	42,91	8,02	28,71	59,54
		Sinop	18	45,77	5,90	33,02	53,71
	N	Adapazarı	18	44,98	7,50	33,18	57,34
		Sinop	18	46,40	7,81	33,85	58,16
Coriolus versicolor	**P**	Adapazarı	18	46,38	5,83	35,04	55,24
		Sinop	18	47,46	4,90	40,29	54,54
	N	Adapazarı	18	44,31	6,18	32,55	56,09
		Sinop	18	48,18	6,80	36,80	56,60
Pleurotus ostreatus	**P**	Adapazarı	18	51,50	5,82	40,04	59,19
		Sinop	18	49,54	5,41	40,73	58,36
	N	Adapazarı	18	50,37	6,71	34,35	62,32
		Sinop	18	50,07	3,81	42,88	61,21

P: Planted NLA, N: Natural NLA.

NLA grown in planted and natural stand, maximum weight loss was occured by *Pleurotus ostreatus,* 51,50 % (planted) and 50,37 % (natural) in Adapazarı, 49,54 % (planted) and 50,07 % (natural) in Sinop, respectivelly.

According to ANOVA, we found there is no significant differences in wood durability against all test fungi for the main effects (region and origin) and interaction between origin and region, origin and fungi, region and fungi (Table 4).

Table 4. Analysis of variance of planted and natural grown NLA wood durability after 12 weeks for *Gloeophyllum trabeum, Coriolus versicolor* and *Pleurotus ostreatus.*

Source of variation	df	Sum of squares	Mean squares	F value	p value
Origin (O)	1	0.028	0.028	0.001	0.979
Region (R)	1	86.199	86.199	2.149	0.144
Fungi (F)	2	997.369	498.684	12.431	0.000
O * R	1	19.481	19.481	0.486	0.487
O* F	2	50.797	25.398	0.633	0.532
R * F	2	118.978	59.489	1.483	0.229
O * R * F	2	47.718	23.859	0.595	0.553
Error	204	8183.785	40.117		
Total	216	491700.868			

There is significant difference between test fungi about weight loss. According to Duncan test for wood rot fungi maximum weight loss shown by *P. ostreatus* (white rot fungi) was 50,15 % than *G. trabeum* was 45,01 % (brown rot fungi) and *C. versicolor* was 46,58 % (white rot fungi) (Figure 4). NLA wood which is grown in plantation and natural stands was more sensitive to white rot fungi, *P. ostreatus* than brown rot fungi, *G. trabeum,* and white rot fungi *C. versicolor.*

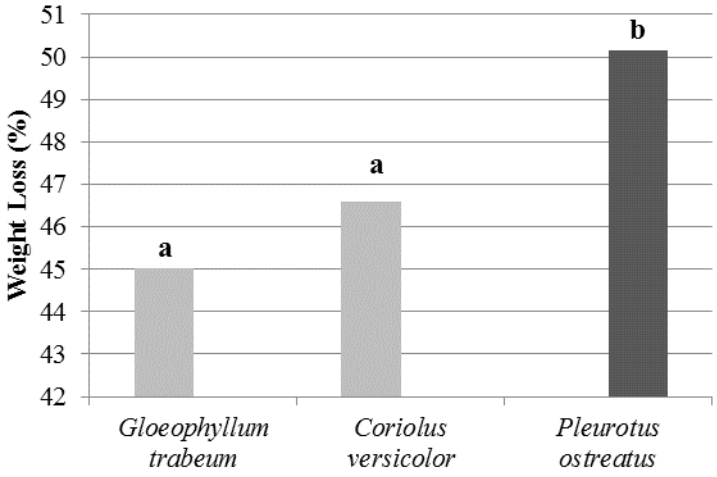

Figure 4. Duncan test result for weight loss by wood decay fungi after 12 weeks exposure.

In this study showed that NLA wood is slightly resistant or nonresistant in durability classification (class IV) and there is no difference between natural and planted NLA wood durability. Naturally grown NLA wood durability class was found in class III (moderately resistant) which were 22 years old and taken from Düzce region, Weight loss was 31,7 % with *G. trabeum* (Yalcin and Sahin, 2015). Related study showed a different durability class for *Fraxinus angustifolia* wood which grown naturally in different site (Düzce region) according to current study. On the other study, decay was found 45.23 % for white rot, and in class III for NLA wood (Nagaveni et al., 2011). Growing site, growth rate, age of trees, portion of wood (heartwood and sapwood), extractive content in wood and environment of the wood being exposed to generally effects the wood durability against fungi (Suprapti, 2010). Although our tree samples were taken different age classes, different region and different origin, natural durability class hasn't change.

One of the white rot fungi, *Pleurotus ostreatus*, has higher weight loss than brown rot fungi (*Gloeophyllum trabeum)* and the other white rot fungi *Coriolus versicolor* but this is not significant statictically. This may be explained by fungal attack, depends on species and strain of fungi (Pildain et al., 2005), ability to degrade lignin (Harsh and Tiwari, 1990). White rot fungi grow better on hardwood species than softwoods (Schmidt, 2006) and more virulent than brown rot fungi (Eaton and Hale, 1993).

There is an opinion about the tree age and growth rate that may affect the durability. Young trees have less or less toxic heartwood extractives than older trees. Thus, young trees are the less durable than the old trees. On the other hand young trees have rapid growth, fast growing trees are less durable if compares with slow growing (Liese, 1970). Opposite of this opininon, although planted NLA trees are younger than natural NLA trees in Sinop, there is no significant differences between planted and natural grown NLA wood durability.

Ash wood was classified as nonresistant in Turkey (Erdin ve Bozkurt, 2013). As a result of present study durability of NLA wood specimens which are grown in plantation and natural stands are slightly resistant or nonresistant (class IV) according to ASTM D 2017-05.

Conclusion

According to results, there is no significant differences between planted and natural NLA wood durability. Both planted and natural NLA wood is non resistant (class IV). Although age class (young, old trees), localities and grown conditions were different, there is no differencce between durability. NLA wood is a little sensitive to one of the white rot fungi, *Pleurotus ostreatus*. Both planted and natural NLA wood can be used for indoor application

but for outdoor application, they may be treated with an environmentally friendly preservatives or applied modification methods to enhance natural durability.

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