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Full Length Research Paper

Determination to the effects of wax/linseed oil and varnish on the dimensional stability of laminated veneer wood (LVL)

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In this study the effects of some protective on the dimensional stability of laminated veneer wood (LVL) was determined. For this purpose, test samples (laminated panels) were glued by various glues, impregnated by the mixture of wax/linseed oil on the basis of ASTM 1413-07 (Standard Test Method of Testing Wood Preservatives by Laboratory Soilblock Cultures) varnished by synthetic based house varnish and waited against the corruptive effects of external environment. Laminated panels were prepared from Pine wood (*Pinus sylvestris* L.) veneer by gluing with Vinyl tree ketonol acetate (VTKA) and melamine formaldehyde (MF) in accordance with TS EN 386 (Glued laminated timber- Performance requirements and minimum production requirements). The samples were impregnated by the mixture of wax/linseed oil and varnished by synthetic based translucent varnish. Control samples (without proceeding), impregnated and varnished samples were kept in the external environment (ASTM G7-05: Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials) for 1 year and in UV environment (ASTM G154-6: Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials, ASTM G151-06: Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources) for 240 hours. The Samples were tested to determine the air-dried density (TS 2472: Wood-Determination of Density for Physical and Mechanical Tests), retention amount (ASTM D 1413-07), dimensional alteration (TS 4084: Determination of swelling in the wood, the radial and tangential direction). According to the results of these tests, in terms of outdoor conditions, it is concluded that the varnished proceeding provides a better protection compared to impregnated proceeding. The best result for dimensional alteration was obtained on the Pine (*Pinus sylvestris* L.) samples with MF glue. The percentage represents the ratio of the natural environment, investing roughly to the external environment has been identified as UV.

Key Words: Laminated veneer lumber (LVL), Pine wood (*Pinus sylvestris* L.), UV ageing, external environment, wax/linseed oil, synthetic based translucent varnish, dimensional alteration.

INTRODUCTION

Physical and economic life of wood material, which is used without any protection and that is not appropriate type of wood, is limited. Prolongation of duration of use by treating with various protective chemicals and improving quality of wood is an important development. Open air conditions that lead to degradation of wood are

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a long-term complex process involving physical events which are often caused by effects of humidity and temperature changes and photochemical reactions. Change of strength properties, strength duration and exposed harmful factors of the type of wood, which will be used in outdoor conditions, should be known (Kurtoğlu 1984, Rowell 1987 and Yazıcı 2005).

Irradiation, thermal radiation, humidity changes, wind, rain, hail, dust, air pollution, micro organisms, photochemical degradation are the factors that affect wood. With the effects of these, orientation conditions of deformation, cracking, leaching, hydrolysis, erosion and discoloration, which will be formed in wood, varies according to the wood properties and time factor. Protection against outdoor weather conditions includes precautions that will be taken against biotic and abiotic wood pests (Rowell, 1987).

Western red cedar, southern pine and beech samples by applying semi-transparent paint, xenon arc lamp using a 6500-W, 45-50 ^{0}C ambient temperature and humidity conditions of 50%, by cycle 1 hour water spray - 6 hr UV applying, 0-50-150 - 300-2400 hours of artificial aging and Wiskosin / Madison was the natural aging. Compared the results of both aging, 4-5 years of natural aging to be equivalent to 2400 hours of UV aging which applied to the unpainted (control) samples have been reported (Erin et al., 1998).

Wood indicates different resistance properties in each type of outdoor weather conditions. Degradation of wood by biological or physical factors will change some of organic compounds. When wood is exposed to outdoor conditions the effect of factors such as humidity and temperature variation, UV rays, chemical weathering, discoloration, corrosion, surface hardening, such as loss of resistance to the separation and the relative changes in annual ring occurs. During certain time periods chemical changes within the wood occur (Yazıcı, 2005). Although, its anatomical and chemical structure of wood due to some outside influence to show adequate strength and natural durability of resistance, wood being open to the weather conditions may not last long. Natural wood is a material susceptible to outdoor weather conditions, wood is impregnated with various chemical substances or can be protected with the non-chemical constructive measures (natural, biological and alternative wood protection) (Kurtoğlu, 1984).

In radial sections, the first change occurring in the anatomical structure of wood occurs at gateways. It is observed that half-edged gateways are damaged in the samples subjected to 500 hours of UV. Especially cracks and gaps on the radial walls are determined; when the waiting time is 1000 hours; it was determined that decay in edged gateways were of much larger or completely fragmentized. In extreme conditions (prolongation of waiting period), the decay is spread to the radial part of tracheid walls and cell walls may decay completely. In some tree species, it is found that, edged gateways disappear with ultraviolet degradation [Feist, and Hon, 1984]. Scots pine test specimens are impregnated with Ammonium Copper Quat (ACQ_2200 and ACQ_1900), chromium copper arsenate (CCA), and Wolmanit tanalith M 3491 CX-8 and are subjected to artificial ageing for 2 hour UV light, 18 minutes water spray (ASTM G-53) and 0,200,400, 600 hours in total. FTIR Spectroscopy damages that occur in samples and color measurement are determined and it is reported that minimum wear is obtained from ACQ-1900 and CCA (Temiz, 2005).

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Increase is observed in the glued laminated material densities of poly vinyl acetate (PVAc), vinyl tree ketonol acetate (VTKA), urea formaldehyde (UF), phenol formaldehyde (beech with PVAc: 0.71 g/cm^3, beech with VTKA: 0.73 g/cm^3, Beech with UF: 0.74 g/cm^3, beech with phenol formaldehyde: 0.78 g/cm^3) than the massive wood (Özçifçi et al., 2007).

In outdoor condition (1 year) the laminated control samples (without transactions) were changed dimension in the thickness 100% -150% more than the width (Doruk, 2009). In this study it was purposed to determine the effects of wax/linseed oil and synthetic based house varnish on the dimensional stability of laminated wood (gluing Vinyl tree ketonol acetate -VTKA and melamine formaldehyde-MF).

MATERIALS AND METHODS

Wood and Glue

In this study Scots pine (*Pinus sylvestris* L.) wood, which known to be resistant to outdoor conditions and used widely in decoration and woodworking industry, was used. Ten layers (10x2 = 20 mm) of laminated components are produced from the parts by the method of cutting, 2 mm thick coating pieces (Colak et al., 2005). Vinyl tree ketonol acetate (VTKA) and melamine formaldehyde (MF) glues which are known their durability to wet places and to environments exposed to external influences were used to bonding of layers. Glue solution was applied to only one surface of layers with 180-200 g/m^2 and they are pressed like following by hydraulic hot

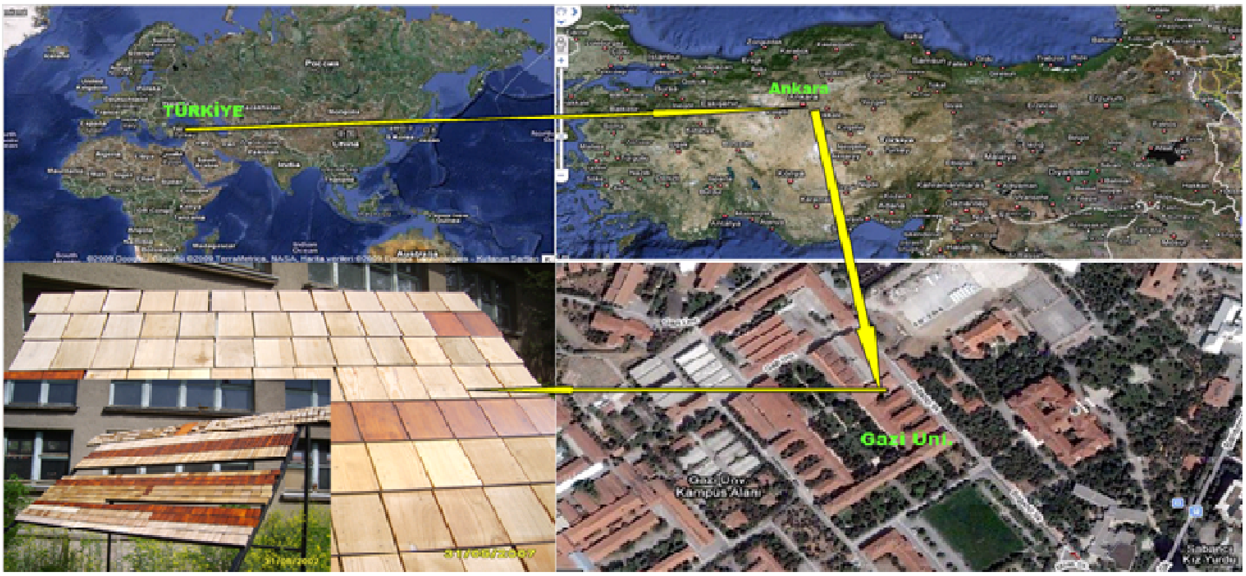

Figure 1: the natural aging on the floor and stand position

press; MF glue at the 80 °C temperature, 12 kg/cm^2 pressure and 20 min., VTKA glue at the 20 °C temperature, 12 kg/cm^2 pressure and 60 min. recommendation of firms. Laminated panels were passed through sandpaper and rubbed both surfaces with emery No. 180 and the thickness has been calibrated. To the detection of dimensional change, test samples 30x65x19 mm dimensions were cut (TS 4084). Obtained test samples were subjected to the application of varnish and impregnation before aging process (Özçifçi et al., 2007).

Protective Materials

Three percent linseed oil - 10% paraffin wax - 87% white spirits (white sprite) solution of water-repellent preservatives and synthetic-based varnish were applied to the test samples as a preservative against the aging. Experimental samples were impregnated on the basis of ASTM D 1413-07 (ASTM-D 1413-07, 2007) principles. Test samples were dried a point of fewer than 20 % moisture content which is for synthetic based varnish. After that, varnish was applied two layers waiting 24 hours after each layer. (Temiz, 2005).

Natural Aging Method (waiting in the external environment)

Control samples (process-free), varnished samples and impregnated samples were placed between 01/05/2007-01/05/2008 one year periods according to the principles of ASTM G7-05 [ASTM G7-05, 2005] standard in Ankara as to face to the south and 45 ° from ground in oblique position given in (Figure 1.)

Accelerated Ageing Method (UV environment waiting)

Control samples (process-free), varnished and impregnated samples were subjected in a laboratory environment according to principles of ASTM G 154-06 (ASTM G 154-06, 2006) and ASTM G 151-06 (ASTM G151-06, 2006). The process was applied in the UV test device as following; accelerated for 8 hours UV 60 (± 3) °C, 4 hours condensation 50 (± 3) °C and with 240 h cyclic program. Accelerated aging test's results were compared to the control samples.

Air Dry Density

Air-dry density was determined according to the principles of TS 2472 using in 20x20x30 mm size samples (TS 2472, 1976). Accordingly, the test samples were kept at 20 ± 2 °C temperatures and 65 ± 5% relative humidity conditions, after reaching weight and dimensional stability, they were measured with the analytical balance with 0.01 g precision. After determining the volumes of the samples with 0.01 mm precision caliper the air dry-density (δ 12) was calculated by the equation (1). Here (Doruk, 2009);

$$\delta_{12} = M_{12} / V_{12} \text{ g/cm}^3 \quad (1)$$

M_{12} = Weight of sample (g)
V_{12} = Volume of sample (cm^3)

Determination of the Retention Amount (kg/m^3)

Impregnation process of experimental samples was

Table 1: the average air dry density of Scots pine control group

Glue Type	δ	s
VTKA	0,58	0,0652
MF	0,58	0,0164

δ: Air-dry density, s: Standard Deviation

Table 2: the amount of retention according to the wood type of Impregnation material (kg/m^3)

Glue type	$\overline{X}$	s
VTKA	163,906	54,248
MF	93,873	11,309

$\overline{X}$: Average value, s: Standard deviation

applied according to the principles of ASTM D 1413-07. Air dry-test samples were subjected to diffusion at atmospheric pressure in solution for 60 minutes after being applied pre-vacuum at impregnation process at a value of 760 mm Hg. After impregnation samples were kept at room conditions for 10-15 days in order for organic solvent to evaporate and air-dried again until it reaches equilibrium moisture content of 12% ± 1. After that the samples were kept again in the cabin air conditioning (at the 20 ± 2˚C temperature and 60 ± 5% relative humidity). Retention amount (R -Kg/m^3) was calculated by equation (2). Here (Doruk, 2009);

$$R = G \times C/V \times 10 \text{ Kg/m}^3 \quad (2)$$

$G = T_2 - T_1$

T_2 = Sample weight after impregnation (g)

T_1 = Sample weight before impregnation (g)

V = Volume of sample (cm^3)

C = Concentration of solution (%)

Dimensional Change (work) measurements

Dimensional change of wood was determined according to the principles of TS 4084. Test samples (each wood type for each transaction type) were prepared in size of 19x30x65 mm [TS 4084, 1983]. Experimental samples were measured to 5 mm from the edge to the inside and from the middle of sample by a digital caliper with accuracy ± 0.01 in the 3 direction of thickness before and after the aging process.

Evaluation of Data

To statistically evaluate the data obtained after the experiments, program SPSS (15.0 version) package is used. The multiple variance analysis was conducted to determine whether the results are significant or not. In case the difference is statistically significant on the factors according to $p < 0.05$, Duncan test was used to determine the size. In comparison, the highest average was symbolized by the letter "A".

RESULTS

Air-Dry Density

Statistical information about air-dry density of test samples is also given in Table 1. Accordingly, intensity values of the laminated test specimens at air dry (12%) VTKA and MF was found to be 0.58 g/cm^3 on the laminated wood. In literature, it is reported that the air dry density of the Scots pine is 0, 52 g/cm^3 (Bozkurt et al., 2000). Air-dry density values of laminated samples (with VTKA and MF glue) are higher than solid wood. This is because to join the high density glue layer between the wood layers and can be pressed with high pressure during lamination. This situation is consistent with the work of "Özçifçi et al., 2007".

The Retention Amount (kg/m^3):

Retention amounts were given in Table 2. Accordingly, highest retention amount obtained as a result of impregnation process with a mixture of paraffin and linseed oil was found 163.906 kg/m^3 in the lamination glued with VTKA. This is because the high viscosity of glue laminated VTKA to be used, to provide bonding VTKA glue just on the surface, the lack of barrier to the penetration of impregnate solution. The viscosity of the Other glue solutions are very low, so it penetrates deep into the structure of the wood hardens and reduces the permeability of the wood.

Dimensional change (swelling %):

Dimensional changes in the direction of thickness of the samples were compared that are subjected to external conditions and UV aging device.

Multiple analyses of variance were given in the Table 3. In order to determine the effect of wood types and Process types on the dimensional stability of laminated wood (LVL); analysis of variance (ANOVA) was applied to the results. DUNCAN test was applied to the mean values of results (using a 95% confidence interval) in order to determine which factors were statistically significant.

Multivariate analysis results regarding the effect of glue type, environment, process, and interactions with test conditions are presented in Table 3.

Table 3: the results of the multiple variance analysis relating dimensional changes in the direction of thickness, process, glue and environment.

Source of variance	Sum ofsquares	Degree of freedom	Mean square	F value	P<5% SignificanceLevel
Glue (A)	0,413	1	0,413	4,143	0,047
Environment (B)	11,008	1	11,008	110,350	0,000
Process (C)	23,434	2	11,717	117,455	0,000
Glue x Environment	0,472	1	0,472	4,729	0,035
Glue x Process	1,036	2	0,518	5,194	0,009
Environment x process	22,007	2	11,003	110,303	0,000
A x B x C	1,489	2	0,744	7,461	0,002
Error	4,788	48	0,100		
Total	112,816	60			

Table 4: the results of the Duncan Test that belong to the dimensional change in the direction of thickness of environment, process and glue type.

Factor		$\overline{X}$	HG
Environment Type	External environment	1,3243	A
	UV	0,4677	B
LSD: 0,8566			
Process type	Control	1,7785	A
	Impregnated	0,4965	B
	Varnish	0,4130	B
LSD: 0,0835			
Glue type	VTKA	0,9790	A
	MF	0,8130	B
LSD: 0,166			

LSD: The most important small range, $\overline{X}$: Average value, HG: Homogeneity groups,

Differences among groups with respect to the effects of variance source on the dimensional change were statistically significant (p=0.05). Duncan's mean comparison test results in Table 4 were conducted to determine the importance of differences among the test groups.

Accordingly, the maximum dimensional change, in terms of environmental factors on the external environments samples1.3243%, in terms of process factors on the control samples 1.7785% and in terms of glue type's factors on the samples glued VTKA Adhesive 0.9790% was obtained.

Results of environment, glue and transaction type interaction dimensional change values in the direction of thickness obtained by the Duncan test are in the Table 5. According Table 5 and Figure 2 dimensional change; the highest in outdoor on the control samples glued MF % 3, 4620 and the lowest in outdoor on the varnished samples glued MF as % 0, 1420 was obtained.

Obtaining high retention of fluid flow from the longitudinal direction at Scots pine and conifer trees may be due to open the gate pairs. Although laminated wood materials are denser than natural wood, they showed less [Keskin, 2001].

DISCUSSION

Based on the each variety of wood, glue-process and environment; expansion of laminated wood material in the form of dimensional change (swelling) was formed. There has been no any shrinkage. Based on environment type in the dimensional change given in Table 5, external environment has been more effective than UV environment. This is because the external environment is very variable and the samples were remained under the snow in the winter.

Control samples (for each wood type) given in Table 5 have been undergone a multi-dimensional change compared to the samples (in their own type) treated with. The reason for this is protection of impregnation and varnishing processes against the dimensional changes of wood.

Based on type of process to prevent dimensional change were benefited 72% by the impregnation process and 77% by the varnish process according to the control samples. This is because the varnish and impregnation process to forming a protective layer on the surface of the samples and stopping moisture into the wood structure.During to wait for long-term in both environment

Table 5: the results of the Duncan test about the rate of dimensional change, which is obtained from interaction between environment, glue and process type.

Process type Environment x Glue		Control $\overline{X}$	HG	Impregnated $\overline{X}$	HG	Varnish $\overline{X}$	HG
Outdoor	VTKA	2,6500	B	0,8080	C	0,4980	CDEF
	MF	3,4620	A	0,3860	CDEF	0,1420	F
UV	VTKA	0,7140	CD	0,6140	CDE	0,5900	CDEF
	MF	0,2880	DEF	0,1780	EF	0,4220	CDEF

LSD: 0.024, $\overline{X}$: Average value, HG: Homogeneity groups,

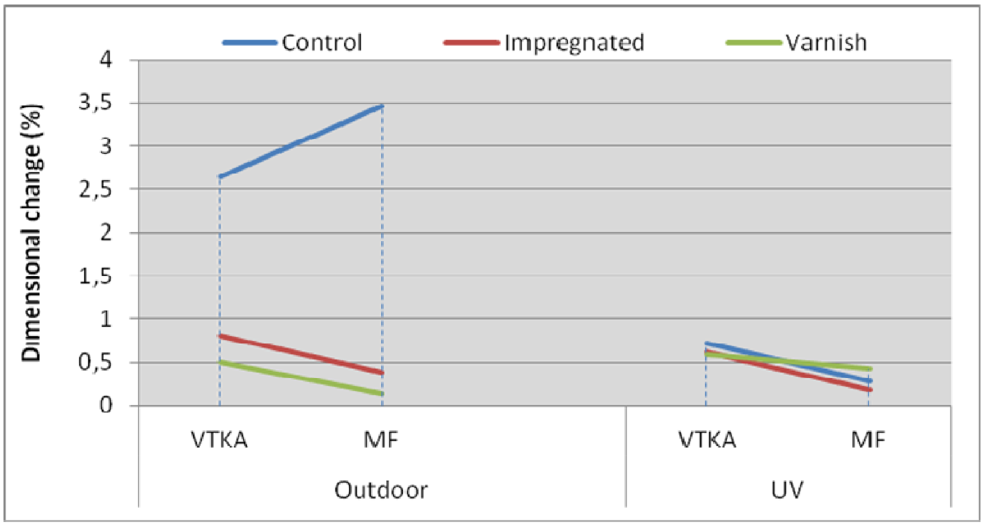

Figure 2 Dimensional changes according to environment, glue and process type

impregnation material the Impregnated samples are washed in water and wood take a small amount of moisture. Therefore, occurred dimensional change on impregnated samples more than varnished samples reported (Rowell and Banks, 1985).

Based on type of glue, the highest expansion amount was obtained on the laminated samples with VTKA. This is because the VTKA is a thermoplastic based adhesive. VTKA is affected by ambient conditions and the dimensional changing of wood material can prevented by VTKA weaker than thermo set-based MF. This is supported literature (Keskin, 2001).

UV- environment is represented 35% of the external environment on the dimensional change process. However, in UV environment by due to impregnating and varnishing to the surface of samples was represented 65% of the external environment. This is mean that the 240-hour aging in UV- environment which corresponds to 65% of 1-year aging by the external environment.

REFERENCES

ASTM G 154-06 (2006). Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials. ASTM, USA, 2-8.

ASTM G151-06 (2006). Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources. ASTM, USA, 3-13.

ASTM G7-05 (2005). Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials. ASTM, USA, 2-10.

ASTM-D 1413-07 (2007). Standard Test Method of Testing Wood Preservatives by Laboratory Soilblock Cultures. ASTM, USA, 1-9.

Bozkurt AY, Goker Y, Erdin N (2000). Wood Anatomy. Rectorate of Istanbul University, 4263:45-49.

Qolak S, Aydin i, Demurkir C, Qolakoglu G (2005). Some Technological Properties of Laminated Veneer Lumber Manufactured from Pine (Pinus sylvestris L) Veneers with melamine Added UF resin. K.T.U. Faculty of Forestry, Forest Industry Engineering Section, Trabzon, 43-45.

Doruk Ş, (2009). Determination of the Effect of aging in wood material laminated Varnish and Preservative Processes. PhD Thesis GU, Institute of Science and Technology, Ankara, 135-136.

Erin L, Pawlak A, Zenon, Owen nL, Feist WC (1998). Infrared Studies of Wood Weathering Part I: Softwoods. Department of Chemistry, Brigham Young University, Provo, Utah 84602 (E.L.A., Z.P., N.L.O.); and Forest Products Laboratory, U.S. Department of Agriculture, Madison, Wisconsin 53705 (W.C.F.) 431-438.

Feist WC, Hon DNS (1984). Chemistry of weathering and protection in the chemistry of solid wood. American Chemical Society, 401-454.

Keskin H (2001). Technological Properties of Laminated Wood Materials and Wood Works Industry User Facilities. PhD Thesis, G.U., Institute of Science and Technology, Ankara, 38-43.

Kurtoglu A (1984). Non-Chemical Method Wood Protection Facilities. Istanbul University, Journal of Forest Faculty, Istanbul, Series B, 4(34):27-29.

Ozgifgi A, Uysal B, Yapici F, Kurt Ş (2007). Effect of to the dimensional

stabilization Under Water Vapor produced by the Different Types of glue laminated wood material (LVL). Technology Journal,10(3): 177-187.
Rowell RM (1987). Treatments that enhance physical properties of wood", U.S. Dept. Of Agriculture, Forest Service, Forest Products Laboratory. Gen. Tech. Report FPL-50:57-58.
Rowell RM, Banks WB (1985). Water Repellency and Dimensional Stability of Wood. U.S.D.A. Forest Prod. Lab, Gen. Tech. Report FPL-50, Madison, Wis., 123-127.
Temiz A (2005). Effects of Simulated External Weather Conditions to the impregnated wood material. PhD Thesis, K.T.U., Institute of Science and Technology, Trabzon, 12-125.
TS 2472 (1976). Determination of Wood-Unit Weight for Physical and Mechanical Tests. Turkish Standards Institute, Ankara, 1-12.
TS 4084 (1983). Determination of swelling in the wood, the radial and tangential direction. Turkish Standards Institute, Ankara, 1-5.
Yazici H (2005). Effect of Strength of Wood Open Air Conditions. Z.K.U Bartin Faculty of Forestry Journal, 7(8) :23-25.
Yildiz UC (1988). Reduction of Water Supply and the dimensional change of various wood types. Master Thesis, K.T.U. Institute of Science and Technology, Trabzon, 28-35.