Chapter 1

Sustainability of Wood Material Treated With Fire Retardants

Haci İsmail KESİK[1],
Kubulay ÇAĞATAY[2]

[1]Gazi University, Faculty of Technology, Department of Wood Products Industrial Engineering, Ankara, Türkiye hismailkesik@gazi.edu.tr,
ORCID: 0000-0003-0900-6671
Google Scholar: https://scholar.google.com.tr/citations?user=ufs6LXoAAAAJ&hl=tr
[2]Yalova University, Faculty of Art and Design, Department of Interior Architecture, Yalova, Turkey, kubulay.cagatay@yalova.edu.tr,
ORCID: 0000-0003-1973-4736
Google Scholar: https://scholar.google.com.tr/citations?user=-jOI7D0AAAAJ&hl=tr

The popularity of wood as a material, whose historical past is changing day by day and which is known to be used in many goods and structures, continues today thanks to some superior characteristics. Natural and healthy, light and robust, high energy efficiency, easy to transport and assemble, aesthetic and decorative, good thermal insulation, resistant to chemicals, economical and sustainable, etc. can be mentioned as examples of the superior properties of wood material (Örs et al., 1999; Bal and Bektaş, 2018).

Sustainability was developed in the Report of the World Environment Conference held in Stockholm in 1972 depending on the discussions within the framework of the concept of eco-development. It was used for the first time in 1987 with the report prepared by the World Commission on Environment and Development (Çetin, 2010). The concept of sustainability is discussed in many environmental, social, economic and cultural dimensions (Brundland R., 1987).

With the technical and technological development that gained momentum after the Industrial Revolution, there has been an eye-catching change in the construction sector. In addition, with the energy crisis in the 1970s, it became clear that one day resources could be depleted. In the following years, it was realized that measures such as environmental pollution, ecology, climate change, etc. should be taken to leave the world as "livable" to future generations. The effect of sustainability in the following stages was seen in the design and production methods of buildings (Çelebi, 2003).

In addition to protecting human health and comfort, sustainable design should support and protect cultural structure, lifestyle and comfort. We can summarize sustainability as taking into account the needs of future generations, not wasting our resources, evaluating waste, not damaging the environment, leaving a livable world for future generations (Aydın and Alemdağ, 2014).

Today, thanks to technological developments, many materials serve the purpose of production in the best possible way, but as their use increases, the decrease in the possible sources of some substances is an important threat to the future (Graedel et al., 2015). Sustainability is positioned at an important point between factors such as production and design studies and environmental problems (Ekşi and Çırak, 2017). The ecological system, process and productivity that exist today are the main elements of sustainability (Yavuz, 2010) and as a key concept, it is in relationship with many disciplines (Güner et al., 2017). It is necessary to evaluate sustainable development in terms of economy, use more in the production process of renewable resources and be responsible for the environmental effects of production activities on the environment (Yavuz, 2010). By preventing environmental problems, the total life span of the products will increase and reduce their costs, thus ensuring sustainability (Ekşi and Çırak,

2017). In this context, it can be said that sustainability is a goal that can be achieved by allowing renewable natural resources to themselves (Yavuz, 2010).

The choice of materials and raw materials are the most important criteria. The crisis of the existence of natural resources, which are already limited, can be prevented by the reuse of materials. This may bring more financial burden, but the important thing is that we need these reserves in the future, and also that this material that is not used will become waste, which will lead to environmental pollution (Pearson, 1998). The negative effects of the artificial environments created on the ecosystem over time force architects to take into account how the environment will be designed and how the buildings will be produced, and lead them to reconsider the designs that cause the least damage to the natural cycle (Gezer, 2013).

Wood and stone, which are very old building materials in human history, have been used as carrier elements, flooring, roof elements and exterior cladding in buildings for thousands of years and continue to be used. These materials have always continued to exist in the field of architecture and design despite the changing materials, construction systems and technologies from the past to the present (Aydın et al., 2014).

The re-evaluation of wood materials preserved from the wreckage of historical wooden buildings in the sustainable construction and furniture sector is important in reducing carbon footprint, saving energy, protecting natural resources and achieving environmental goals such as climate change (URL 1, 2024). However, the fact that the wood material is not resistant to adverse weather conditions and biological effects, especially its low fire resistance, still makes people nervous. Fortunately, today, the life of the treated wood material is increasing with different modifications, impregnations and protective layers newly developed. In archaeological studies, it has been determined that fire retardants, various varnishes and paints (Eickner, 1966, Ellis and Rowell, 1989) have been applied to wood materials and have been preserved until today.

In some research, the Greeks used seawater, the Egyptians used aluminium solutions, and the Romans used clay, lime, slime (Bozkurt, 1997), alum and vinegar (Eickner, 1966) as fire retardants. The impregnation of wood materials with chemicals is important in order to increase their resistance to combustion in many places of use (Ellis and Rowell, 1989).

Wood material is a sustainable building material with low carbon emissions produced with natural, edible, low energy (Binggeli, 2008). It is stated that the amount of carbon released from building materials in wood production is 15 kg/m^3, 120 kg/m^3 in concrete production, 5320 kg/m^3 in steel production and 22000 kg/m^3 in aluminium production. The sustainability of wood material can

be ensured through practices such as correct afforestation studies, conscious tree cutting, utilization of wastes in composite material production and use of alternative wood sources (Çelebi, 2003; Binggeli, 2008).

Combustion is one of the most important disadvantages of wood materials (Istek et al., 2017). In the first phase of the wood combustion process, the wood is exposed to heat and water vapour is released (White and Dietenberger, 2010). In the second stage, cellulose, hemicellulose and lignin, which are the components of wood, are broken down by heat and their thermal degradation begins (Babrauskas, 2003) and flammable gases are released. In the third stage, these gases catch fire and combustion continues. Finally, at the end of the combustion process, charred residues and ash are formed. During these phases, the rate of wood combustion and the rate of flame propagation vary depending on the type of wood, its density, and its moisture content (White and Dietenberger, 2010).

Various methods are used to increase the combustion resistance of wood materials. One of these methods is to apply fire-retardant chemicals to the wood. Fire retardant chemicals ensure fire safety by increasing the resistance of wood to heat and slowing down the combustion process. These chemicals can be applied to the surface or internal structure of the wood and change the combustion properties of the wood through various chemical reactions (LeVan and Winandy, 1990).

There are changes in some physical and mechanical properties of the tree material traded with fire retardant chemicals (Demir and Aydın, 2016). In general, fire retardants should reduce the flammability of wood material, prevent the spread of flame between surfaces, and reduce the rate of degradation and charring. When the heat source is removed, the wood should stop the combustion of the material and prevent ignition (Küçükosmanoğlu, 1993).

Fire retardant chemicals both slow down the heat breakdown process of wood components and increase fire safety by reducing the formation of flammable gases. In this process, phosphates, borates and halogenated compounds from fire retardants (LeVan and Winandy, 1990), and finishing materials (Budakçı et al., 2016) are widely applied to wood material by different methods. These substances increase the carbonization of wood during combustion and slow down the spread of flames by absorbing heat. However, the effects of these chemicals can vary depending on the type of wood, method of application, and conditions of use. Fire retardants such as phosphates, borates and halogenated compounds increase the carbonization of wood during combustion and reduce the formation of flammable gases. Phosphates provide resistance to heat by forming a protective layer on the surface of the wood. Mixtures such as borates (Baysal et al., 2006)

and Firetex (Kesik et al., 2016) slow down the thermal degradation of wood and reduce the formation of flammable gases (LeVan and Winandy, 1990; Kartal and Green, 2003) and reduce the risk of fire. Halogenated compounds, on the other hand, inhibit combustion reactions by forming free radicals and stop the combustion process (Babrauskas, 2003).

If the wood material is to be used in outdoor conditions, fire retardant chemicals may lose their effect due to the effect of precipitation. The effect of fire retardants may vary depending on the method of application (Örs et al., 1999, Kesik et al. 2024). It has been reported that the amount of absorption of fire retardant chemicals will increase depending on the immersion time in the immersion method (Demir and Aydın, 2021) and that it will give more positive results in the pressure method than the immersion method (Uysal, 1997). They determined that the weight loss (31.37%) was less than 1/3 of the control samples and the CO gas emission (80.17 ppm) was less than half of the control samples in Scotch pine wood where long-term immersion method was applied with fire retardant solutions (Kesik et al., 2015).

The application of fire-retardant protective layers can also increase the fire resistance of wood material (Östman and Tsantaridis, 2016). Today, in addition to timber, contra, composite and particle boards impregnated with fire-retardant chemicals, new ones are added to the market every day by adding new ones to those whose surfaces are coated with fire-retardant paints (Östman, et al., 2017). As industrialization and technological developments increase; The search for environmentally friendly, non-toxic, high temperature and flame resistant, functional materials with wide applicability is also increasing (Aydın et al., 2016).

Processing wood material, which is one of the limited natural resources, with environmentally friendly protectors will contribute to the maximum level of economic life and thus to its sustainability. Increasing the fire resistance of wood material is of great importance, especially in terms of fire safety. Therefore, researching and developing the effects of fire retardant chemicals on wood materials, improving fire safety standards (Östman et al., 2017), and making wooden structures safer play a critical role in terms of sustainability. In this study, the single flame-induced combustion resistance of Scotch pine wood material protected by water-based fire retardants will be determined.

The experimental method used to determine the resistance of single flame-induced combustion resistance, the combustion values and findings of wood materials treated with impregnation, fire retardant solution and water-based paints are given below, respectively.

In this study, Scotch pine (*Pinus sylvestris* L.) wood, which is widely used in the woodworking and construction industry, was preferred as an experimental sample. In this study, solution (Hemel FR), impregnation (Hemel Prime), green water-based paint (Y-D 45) and black water-based paint (S-D 45) were used as fire retardants. Fire retardant solutions were procured from enterprises in Ankara, and water-based paints were supplied from Kimetsan. Test specimens treated with impregnated Hemel Prime, fire retardants Hemel FR, Kimetsan Black-D45 and Kimetsan Green-D45 were exposed to single flame-induced combustion and the combustion zone was measured.

Statistical analyses were performed using the IBM SPSS 27 program using the data obtained from the experimental samples. Single analysis of variance (ANOVA) was performed to examine the data obtained, the Duncan test was performed to compare the variables considered important in the analysis of variance with each other and homogeneity groups were determined.

The properties of fire retardant solutions are taken from the company websites (URL2, 2024) and the paint properties are taken from the manufacturer (D45 MSDS, 2015) and are given in Table 1.

Table 1. Features of fire retardant solutions, impregnations and paints

Fire retardants	Hemel FR	Hemel Prime	Kimetsan Y-D45	Kimetsan S-D45
Density (g/cm^3)	1,09 ± 0,02	1 ± 0,02	1,17	1,23
Amount of solids	11,8	14,3	23,7	24,5
VOC (g/L)	10	0	<50	<50
Shelf Life (5-35°C)	2 years	2 years	2 years	2 years
Covering Capacity (m^2/L)	Single layer 4-5	4-5	8-10	8-10
Drying Time (20°C, %40-65 Relative humidity)	24 hours	24 hours	24 hours	24 hours
Colour	Colourless	Brown	Light green	Black

The test specimens were prepared in 8x32x1 cm dimensions and kept in the air conditioning cabinet with a temperature of 20±2°C and a relative humidity of 65±3% according to TS 2471 until they reached a constant weight. Fire retardant Hemel FR+Kimetsan D45, Hemel Prime+Kimetsan D45 and Kimetsan D45 brushes were applied to the surfaces of the test samples in three coats.

In the single flame combustion test, the burner tip angle from which the flame comes out is fixed to 45o, and the test is placed directly opposite the sample surfaces. After fixing the flame length of 20 mm and the distance between the flame and the test samples of 2 mm, the test samples were left to be exposed to flame for 60 seconds (Figure 1) (TS EN ISO 11925-2).



Figure 1. Combustion assembly

After the combustion period was completed, the combustion continued on the surfaces of a few of the experimental specimens from which the flame source was drawn, while the combustion did not continue in the others. At the end of the test, the burn zones on the samples were visually examined and the dimensions of the burn marks were measured and recorded separately. The area where the flame affected in the first degree (burning zone) was burned and blackened, and pit formation and cracks occurred in the combustion zone of some samples.

Experimental samples exposed to flame for 60 seconds; traded with Kimetsan Green-D45 (Figure 2a), traded with Hemel FR+Kimetsan Green-D45 (Figure 2b), traded with Hemel Prime+Kimetsan Green-D45 (Figure 2c), traded with Hemel Prime+Hemel FR+Kimetsan Green-D45 (Figure 2d); is given.

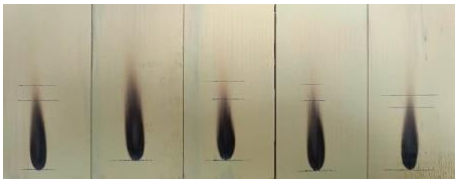


Figure 2a. Kimetsan Green-D45

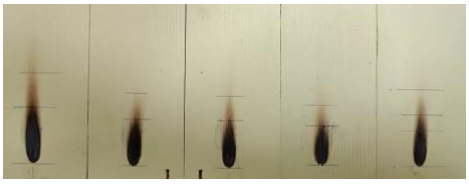


Figure 2b. Hemel FR+Kimetsan Green-D45

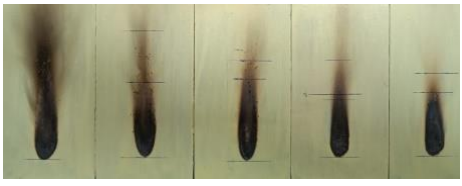


Figure 2c. Hemel Prime+Kimetsan Green-D45

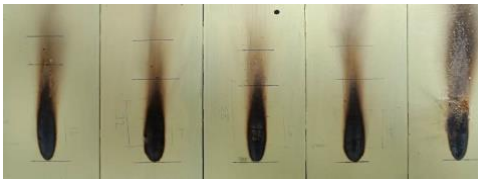


Figure 2d. Hemel FR+Hemel Prime+Kimetsan Green-D45

Experimental samples exposed to flame for 60 seconds; traded with Kimetsan Black-D45 (Figure 3a), traded with Hemel FR+Kimetsan Black-D45 (Figure 3b), traded with Hemel Prime+Kimetsan Black-D45 (Figure 3c), traded with Hemel Prime+Hemel FR+Kimetsan Black-D45 (Figure 3d); is given.



Figure 3a. Kimetsan Black-D45



Figure 3b. Hemel FR+Kimetsan Green-D45



Figure 3c. Hemel Prime+Kimetsan Green-D45



Figure 3d. Hemel FR+Hemel Prime+Kimetsan Green-D45

The analysis of the variance of the dimensions of the burn marks on the surfaces of the experimental specimens left to be exposed to flame for 60 seconds is given in Table 2.

Table 2. Analysis of variance of combustion trace dimensions in experimental samples

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5393,375	7	770,482	15,310	0,000*
Within Groups	1610,400	32	50,325		
Total	7003,775	39			

*: Meaningful (according to $\alpha < 0.05$)

According to Table 2, statistically significant differences were found in fire retardants ($p \leq 0.05$). The results of the comparison of Duncan test burn trace values at the level of fire retardant treatment type are given in Table 3.

Table 3. Duncan test at the level of fire retardant treatment type

Fire retardants	$\overline{X}$	**SD**	**HG**
Kimetsan Green-D45	55,60	3,78	BC
Kimetsan Black-D45	68,20	5,40	D
Hemel FR+Kimetsan Green-D45	39,80	5,63	A*
Hemel FR+Kimetsan Black-D45	53,80	6,42	B

Hemel Prime+Kimetsan Green-D45	64,00	13,21	BD
Hemel Prime+Kimetsan Black-D45	78,60	8,02	E
Hemel FR+Hemel Prime+Kimetsan Green-D45	66,80	4,60	D
Hemel Prime+Hemel FR+Kimetsan Siyah-D45	73,80	5,12	DE

$\overline{X}$: Arithmetic average, HG: Homogeneous groups, SD: Std. Deviation

According to Table 3, in the experimental samples exposed to the combustion effect caused by a single flame for 60 seconds; It was the lowest in those traded with Hemel FR+Kimetsan Green-D45 (39.8mm) and the highest in those traded with Hemel Prime+Kimetsan Black-D45 (78.6mm); Combustion trace values were determined. The low burn scar length in the burning areas indicates that the fire retardants used are successful.

In this study, the fire resistance properties of Scotch pine wood materials exposed to the combustion effect caused by a single flame vary with the effect of impregnating agent (Hemel Prime), different fire-retardant solutions (Hemel FR) and paints (Kimetsan Y-D45, Kimetsan S-D45). In the study, it was thought that the combustion resistance properties would increase by applying the impregnating agent and fire-retardant solution to the sample surfaces consecutively and then coating them with fire retardant water-based paints. However, the opposite situation was determined in solution applications made after impregnation. This may because the impregnating agent applied before does not accept much of the solution, as it fills the surface of the tree. Applying fire retardants with a brush can be effective in this outcome. In the literature (Kesik et al., 2024), they reported that when different fire retardants were applied to wood material consecutively, they increased the combustion resistance more than the control samples. This view supports the results of the study.

Fire retardant paint applications were made with brushes, and paint covering was provided especially in third coat applications on Hemel FR. It is thought that applications with spray guns will be easier. In the study, it was determined that the application of Hemel FR+Kimetsan Yeşil-D45 increased the fire resistance and gave the most successful result. It is thought that the application of fire retardants such as Hemel Prime and Hemel FR with different application methods will penetrate deep into the wood material and increase fire resistance. The literature (Yalınkılıç, 1992; Uysal et al., 2000) supports our view by stating that impregnation with immersion and pressure method will give positive results. Users may be advised to choose one of the immersion or pressure methods in fire retardant applications. In future studies, CO measurements can be made in wood materials with fire retardant and its impact on the environment can be discussed.

References

Aydın D.Y., Gürü M., Ayar B., Çakanyıldırım Ç. (2016). Bor bileşiklerinin alev geciktirici ve yüksek sıcaklığa dayanıklı pigment olarak uygulanabilirliği, BORON 1 (1), 33 – 39.

Aydın, Ö. and Lakot Alemdağ, E. (2014). Karadeniz Geleneksel Mimarisinde Sürdürülebilir Malzemeler; Ahşap Ve Taş. Journal Of International Social Research, 7(35).

Babrauskas, V. (2003). Ignition Handbook: Principles and Applications to Fire Safety Engineering, Fire Investigation, Risk Management and Forensic Science. FireScience Publishers.

Bal, B. C and Bektaş, İ. (2018). Determination of relationship between density and some physical properties in beech and poplar wood, Furniture and Wooden Material Research Journal, 1(1):1-10.

Baysal E., Sönmez A., Çolak M., Toker H. (2006). "Boratlar ve su iticilerle işlenmiş odunun sızıntı miktarı ve su emilim düzeyleri." Biyolojik Kaynak Teknolojisi 97: 2271-2279.

Binggeli, C. (2008). Materials for interior environments. John Wiley & Sons.

Bozkurt, E. (1997). Evolution of a mid-Tertiary extensional shear zone in the southern Menderes Massif, western Turkey.

Budakçı, M., Esen, R., Özcan, C., Korkmaz, M., Pelit, H. (2016). The Effect of Boric Acid Modification on the Combustion Properties of Water-Based Varnish, II. International Furniture Congress, 36-42, 13-15 October 2016, Muğla, TURKEY

Brundland Report, (1987). Report of the World Commission on Environment and Development: Our Common Future. Access Date: 23.12.2024. file:///C:/Users/VivoBook/OneDrive/Masa%C3%BCst%C3%BC/our_common_futurebrundtlandreport1987.pdf

Çelebi, G. (2003). "Çevresel Söylem ve Sürdürülebilir Mimarlık için Kavramsal Bir Çerçeve", G.Ü. Fen Bilimleri Dergisi, C. 16, s.205-216

Çetin, S. (2010). Geleneksel konut mimarisinin ekolojik yansımaları: Burdur örneği. 5. Ulusal Çatı & Cephe Sempozyumu, 15-16.

D45 Malzeme Güvenlik Bilgi Formu, (2000). D45 Su Bazlı Boya, Kimetsan Ltd. Şti., 15.06.2000.

Demir, A. and Aydın, İ. (2021). Yangın Geciktirici Kimyasallarla Emprenye Edilmiş Kontrplakların Formaldehit Emisyonlarının Yapay Sinir Ağları İle Tahmini, Turkish Journal of Forest Science, 5(2), 352-365

Demir, A. and Aydın, İ. (2016). Yangın Geciktirici Kimyasal Maddeler ile Emprenye İşleminin Odun ve Odun Esaslı Malzemelerin Teknolojik Özellikleri Üzerine Etkileri, Ormancılık Dergisi 12(1):96-104.

Eickner, H. W. (1966). Fire Retardant Treated Wood, Journal of Materials, 625-644.

Ekşi, G. & Çırak, C. R. (2017). Farklı bakış açılarıyla LCA incelemesi. Hacettepe Üniversitesi, Ocak. Erişim adresi: https://d1wqtxts1xzle7.cloudfront.net/51344961/Farkli_Bakis_Acilariyla_LCA_Incelemesi

Ellis D.W. and Rowell M.R. (1989). Flame-Retardant Treatment of Wood with a Diisocynate and an Oligomer Phosphonate, Wood and Fiber Science, 21(4):367-375.

Gezer, H. (2013). Geleneksel Safranbolu Evlerinin Sürdürülebilirlik Açısından Değerlendirilmesi. *İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi*, *12*(23): 13-31.

Graedel, T. E., Harper, E. M., Nassar, N. T. & Reck, B. K. (2015). On the materials basis of modern society. Proceedings of the National Academy of Sciences, 112(20), 6295-6300. https://doi.org/10.1073/pnas.1312752110

Güner, C., Gökşen, F. & Koçhan, A. (2017). Sürdürülebilir kalkınma modeli için çevre duyarlı yapılarda malzeme seçiminin incelenmesi. Akademia Disiplinlerarası Bilimsel Araştırmalar Dergisi, 3(2), 1-14. Erişim adresi: https://dergipark.org.tr/en/pub/adbad/issue/33581/338091).

İstek, A., Özlüsoylu, İ., Çelik, S. and Gönü, Ş. (2017). Ahşap Esaslı Levha Sektöründe Kullanılan Yanma Geciktiriciler, 4. Uluslararası Mobilya ve Dekorasyon Kongresi, 15.12.2017, 6(3):389-399. https://dergipark.org.tr/tr/download/article-file/379124

Kartal, S. N., & Green, F. (2003). Decay and termite resistance of medium density fiberboard (MDF) made from different wood species and boron compounds. International Biodeterioration & Biodegradation, 52(2):125-133.

Kesik H.I., Aydoğan H., Çağatay K., Özkan O.E., Maraz E. (2015). Fire Properties of Scots Pine Impregnated with Firetex, 1st International Conference on Environmental Science and Technology, Bosna-Hersek, Sarajevo, 9-3 September 2015, p.122-127. https://www.researchgate.net/publication/282650055_Fire_Properties_of_Scots_Pine_Impregnated_with_Firetex

Kesik H.I., Aydoğan H., Özkan O.E., Maraz E. (2016). Combustion properties of Turkish fir impregnated with Firetex, 2nd International Furniture Congress Proceedings, 13-15 October 2016, Muğla, Türkiye, p.150-153.

Kesik, H.İ., Özdemir, O., & Çağatay, K. (2024). December 06-08). Effect of Some Fire Retardants on Single Flame Combustion Resistance of Scotch Pine Wood Materials, UMTEB-XVI International Scientific Research

Congress, Adana, (p. 1415-1421). https://www.umteb.org/_files/ugd/d0a9b7_53c830accd0247e3a5bb03bbed965560.pdf

Küçükosmanoğlu, A., (1993). Ahşap malzemenin yanma özellikleri ve binalarda yangın güvenliği, İstanbul Ün. Orman Fakültesi Dergisi Seri B, 43(3-4):145-151.

LeVan, S. L., & Winandy, J. E. (1990). Effects of Fire Retardant Treatments on Wood Strength: A Review. Wood and Fiber Science, 22(1), 113-131.

Örs, Y., Sönmez, A., and Uysal, B. (1999). "Ağaç Malzemenin Yanmaya Dayanıklılığını Etkileyen Emprenye Maddeleri", Turkish Journal of Agriculture and Forestry, vol. 23(2):389-394.

Östman, B. & Tsantaridis, L. (2016). Dış mekan uygulamalarında yangın geciktirici uygulanmış (FRT) ahşap ürünler için yangına tepki performansının dayanıklılığı - on yıllık bir rapor. *MATEC Web of Conferences'da* (Cilt 46, s. 05005). EDP Sciences.

Östman, B., Brandon, D. And Frantzich, H. (2017). Fire safety engineering in timber buildings, Fire Safety Journal, 91:11-20.

Pearson, D. (1998). The new natural house book: creating a healthy, harmonious, and ecologically sound home. Simon and Schuster.

TS 2471. (2005). Wood, determination of moisture content for physical and mechanical tests. Odunda, fiziksel ve mekaniksel deneyler için rutubet miktarı tayini.

TS EN ISO 11925-2, (2004). Yapı malzemeleri- Yangın dayanımı deneyleri- Aleve doğrudan maruz kaldığında tutuşabilirlik- Bölüm 2: Tek alev kaynağıyla deney, TSE.

URL 1, (2024). Ağaçların İnşaat ve Mobilya Endüstrisinde Kullanımı, 17.12.2024 tarihinde https://bizimdergi.com/agaclarin-insaat-ve-mobilya-endustrisinde-kullanimi/ adresinden erişildi.

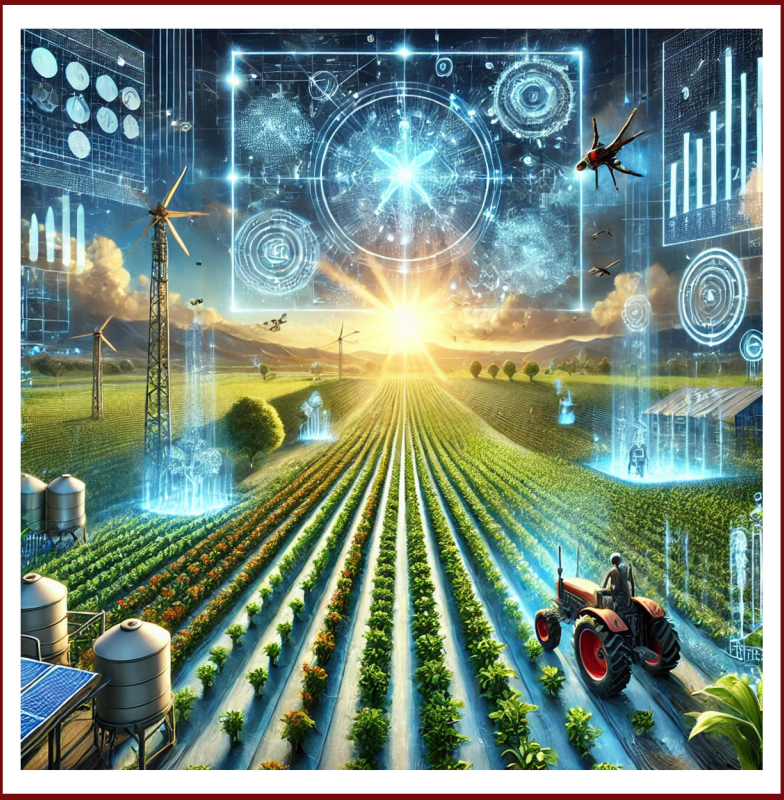
URL2, (2024). HEMEL FR 22.12.2024 tarihinde https://www.hemel.com.tr/hemel-fr-seffaf-yangin-geciktirici-solusyon?srsltid=AfmBOorY-XJLR9Kaqpek66q5mzmg2dwHLx5WfV7cvrOzo_P0sitc1mUK adresinden erişildi.

Uysal B. (1997). “The impacts of various chemical materials on combustion resistance of wood material,” Ph.D. Thesis, Gazi University Institute of Applied Sci., Ankara, 96-99.

White, R. H., & Dietenberger, M. A. (2010). Fire Safety of Wood Construction. In *Forest Products Laboratory, Wood Handbook: Wood as an Engineering*

Material (pp. 18-1–18-19). USDA Forest Service, Forest Products Laboratory.

Yavuz, V. A. (2010). Sürdürülebilirlik kavramı ve işletmeler açısından sürdürülebilir üretim stratejileri/concept of sustainability and sustainable production strategies for business practices. Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 7(14), 63-86. Erişim adresi: https://dergipark.org.tr/en/pub/mkusbed/issue/19556/208640



AGRICULTURE, FOREST AND AQUATIC SCIENCES IN THEORY AND PRACTICE

Editörler
Assoc. Prof. Dr. Vedat ÇAVUŞ
Asst. Prof. Dr. Senem GÜNEŞ ŞEN

DUVAR

AGRICULTURE, FOREST AND AQUATIC SCIENCES IN THEORY AND PRACTICE

Editors:

Assoc. Prof. Dr. Vedat ÇAVUŞ

Asst. Prof. Senem GÜNEŞ ŞEN



AGRICULTURE, FOREST AND AQUATIC SCIENCES IN THEORY AND PRACTICE
Editor: Assoc. Prof. Dr. Vedat ÇAVUŞ, Asst. Prof. Senem GÜNEŞ ŞEN

Editor in chief: Berkan Balpetek
Cover and Page Design: Duvar Design
Printing : December -2024
Publisher Certificate No: 49837
ISBN: 978-625-5530-89-9

© Duvar Yayınları
853 Sokak No:13 P.10 Kemeraltı-Konak/İzmir
Tel: 0 232 484 88 68

www.duvaryayinlari.com
duvarkitabevi@gmail.com

The publisher and editors are not obligated to accept responsibility for the views, opinions, and potential ethical violations stated by the authors. The responsibility for the content in the book lies solely with the author(s).

TABLE OF CONTENTS

Chapter 1.....6

Sustainability of Wood Material Treated With Fire Retardants

Haci İsmail KESİK, Kubulay ÇAĞATAY

Chapter 2.....19

Organic Fertilizer Use in Crop Production

Ahmet Safak MALTAS

3. Bölüm.....36

Macro Element Deficiencies in Plants

Ahmet Safak MALTAS

Chapter 4.....50

Pesticides and Effects On Aquatic Ecosystem

Ayşe GÜNDOĞDU

Chapter 5.....77

Adaptation Challenges: Wheat Production Under Changing Climatic Conditions In Pakistan

Haroon KHAN, Ömer Süha USLU, Osman GEDİK

Chapter 6.....90

The Use Of Insects As Natural Dyestuffs

Gökhan AYDIN

Chapter 7.....113

Manupulation Of Growth And

Abiotic Stress Resistance Via Salicylic Acid (SA) in Plants

Burçak KAPUR, Uğur KEKEÇ

Chapter 8.....130

Zebra Mussel Problem In Inland Waters

Ebru İfakat ÖZCAN, Sinan ÖZCAN

Chapter 9.....140

Turkey Endemic Fish Species and Characteristics Belonging to the Cobitidae Family

Sinan ÖZCAN, Ebru İfakat ÖZCAN

Chapter 10.....151

Effects Of Soil Zinc Application On Phytic Acid/Zinc Ratio And Phytase Activity In Grains Of Different Cereal Species

İbrahim ERDAL

Chapter 11.....170

The Potential Use Of Remote Sensing Technologies And Unmanned Aerial Vehicles (UAVs) In Agricultural Fields

Mehmet SENER, Selcuk ALBUT

Chapter 12.....190

The Use of Artificial Intelligence in Watershed Management

Saim YILDIRIMER1

Chapter 13.....212

Harnessing the Potential of Underutilized and Indigenous Vegetables (UIVs): A Pathway to Sustainable Food Systems and Nutrition Security

Suat ŞENSOY1

Chapter 14.....235

Genetic Approaches to Enhancing Nutritional Quality in Vegetables through Nutraceutical Breeding

Suat ŞENSOY

CHAPTER 15.....255

Stem Cell-Based Seafood Production in Aquaculture

Şehriban ÇEK, Fatmagün AYDIN