

Evaluation of the Flammability of Trees and Shrubs Used in the Implementation of Green Barriers in Southern Brazil¹

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Abstract

The purpose of green barriers, also known as green fuelbreaks, is to reduce the spread and intensity of fire, mainly by stopping it from spreading to the treetops, which facilitates fire control and suppression. A major difficulty in implementing green barriers is to identify suitable species for forming these structures. The aim of this study was to assess the flammability of some tree and shrub species used in urban forestry and along highways in Curitiba for use in green barriers in the rural-urban interface of cities in southern Brazil. To this end, fire behavior and flammability tests (epiradiator trials) were performed in the Forest Fire Laboratory at the Universidad Federal de Paraná on the following species: *Magnolia grandiflora* L., *Michelia champaca* L., *Jasminum mesnyi* Hance, *Casearia sylvestris* Sw. and *Viburnum odoratissimum* Ker Gawl. Test results showed that the species *J. mesnyi* is extremely flammable (FV = 5), *M. grandiflora* and *C. sylvestris* are highly flammable (FV = 4), and the species *V. odoratissimum* and *M. champaca* are moderately flammable (FV = 3) and low flammability, respectively.

Keywords: epiradiator, flammability, fire prevention.

Introduction

Establishing firebreak areas to prevent or reduce the spread of fire from one area to another is a very simple and effective preventative forestry technique, especially in large reforested areas with highly flammable species, such as conifers.

A firebreak is a barrier or a change from a highly flammable fuel to a less

¹An abbreviated version of this paper was presented at the Fourth International Symposium on Fire Economics, Planning, and Policy: Climate Change and Wildfires, November 5-11, 2012; Mexico City, Mexico.

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flammable one. Firebreaks can be natural (a river or deciduous forest) or artificial (FPInnovations 2009). Manmade green barriers are strategically placed to protect the assets at risk and are generally wide or narrow strips in which dense or flammable vegetation is continuously changed for a cover with lower volume and / or low flammability (Green 1977). Plant material is always fuel, but not always flammable. Flammability varies by species and moisture content (Vélez 2000).

The objective of the green barrier is to reduce the spread and intensity of fire, mainly by stopping it from spreading to the treetops and thereby facilitating fire control and suppression. Tian and others (2007) find that green barriers play an important role in fuel management and landscape management systems.

In Brazil, green barriers, also known as "green fuelbreaks," are little known and little used in forest fire prevention, despite having been recommended for many years in forest fire prevention and suppression manuals (Batista and Soares 2008, Ribeiro and others 2007, Soares and Batista 2007).

One of the major difficulties in implementing green barriers is to identify suitable species for formation of these structures.

The aim of this study was to assess the flammability of some species of trees and shrubs used in urban forestry and along highways in Curitiba for use in green barriers in the urban-rural interface of cities in southern Brazil, through the method established by Valette (1990) and recognized by researchers from other world regions.

Methods

All laboratory and open area experiments required for carrying out the research were performed in the Forestry Department's Forest Fire Laboratory at the Universidad Federal de Paraná.

The species used in the experiments were selected based on the characteristics of tree and shrub species described by Biondi (2002), Lorenzi (1992), Lorenzi (1998), Lorenzi and Souza (2001), Lorenzi and others (2003) and on the methodology proposed by Biondi and Batista (2010). The species selected were:

- *Jasminum mesnyi* Hance, fam. Oleaceae: a perennial shrub with semi-herbaceous texture, scandent, native to China, with many long branches 2-3 m long, with dense and bright foliage, grown in full sun, preferably in high places to allow the formation of bending stems (Lorenzi and Souza 2001);

- *Michelia champaca* L, fam. Magnoliaceae: evergreen tree 7-10 m tall, native to India and the Himalayas, cylindrical stem with slightly fissured bark, with branches arranged to form a characteristic pyramidal canopy in juvenile stage,

simple alternate leaves, 10-18 cm long (Lorenzi and others 2003);

- *Casearia silvestris* SW, fam. Flacourtiaceae: tree 4-6 m high, persistent leaves, glabrous or rough and shiny on top, 6-12 cm long, is a hardy, perennial, heliophilous pioneer plant (Lorenzi 1992) and slow growing (Carvalho 2006);

- *Viburnum odoratissimum* Ker Gawl., fam. Magnoliaceae: evergreen tree, 5-7 m tall, native to India, China and Japan, stem with rough bark with lenticels, slow growing, very hardy and tolerant to adverse soil and climate conditions (Lorenzi and Souza 2003);

- *Magnolia grandiflora* L. , fam. Magnoliaceae: evergreen tree, 12-15 m tall, native to the United States, irregular stem with uneven bark, with vigorous branches forming pyramidal canopy in youth and open canopy in old age, has simple alternate leaves, clustered at the ends of branches, coriaceous, persistent, 6-12 cm long, is a slow growing and long-lived tree (Lorenzi and Souza 2003).

According to Biondi and Batista (2010), in order for species to be suitable for use in green barriers, their characteristics must meet certain requirements regarding low flammability to hinder the ignition and spread of fire. Thus, for example, the species should be hardier, with an oval or pyramidal canopy, which are the simplest shapes for uniting the canopies through a set spacing. It must have monopodic branching, which facilitates the canopies crossing one another and has fewer gaps in the canopy and on the stem. The leaves should have a fleshy, herbaceous or coriaceous texture, with smooth, shiny surfaces, and they should have high water content and be without villi, which favor ignition. The stem should have dead, even bark without peeling, as this helps protect the tree whereas detached bark provides more combustible material. The species must have moderate to rapid growth, in reference to the time it takes to form the barrier and the speed with which the species recovers from fire damage.

To perform the experiments, leaves and thin branches (< 0.7 cm in diameter) were collected from the tops of the preselected species. Then the material was placed in airtight plastic bags, weighed and identified in detail. It was then sent to the Forest Fire Laboratory, where moisture content was determined using standardized procedures. The moisture content of the material collected was determined by the following formula (Batista and Soares 2007):

$$U\% = ((WW - DW) / DW) \times 100 \quad (1)$$

where U% is the moisture content of the combustible material (in %), WW is weight (wet) of material at the time of collection, and DW is weight (dry) of material after drying in an oven at 75 °C for 48 hours.

The flammability tests were performed according to the methodology proposed by Petriccione and others (2006) y Petriccione (2006). An epiradiator delivering a 500W constant nominal power rating with a temperature of 250 °C was used. Each 1-gram sample in natural state was exposed to the epiradiator for 60 seconds, with 50 trials conducted for each species. Ignition potential was determined by the average time for combustion to occur after the material was exposed to the epiradiator (for longer than 60 seconds, the test is considered negative). Combustion period, that is, the time the flame remains visible, and flame length were also measured.

Flammability values were obtained from ignition potential (IP) and the mean time to ignition (MTI), based on Table 1 (Valette 1990).

Table 1—*Flammability values (Valette, 1990)*

PI MDI– s	< 25	25-38	39-48	42-44	45-47	48-50
>32,5	0	0	0	1	1	2
27,5 – 32,5	0	0	1	1	2	2
22,5 – 27,5	0	0	1	2	2	2
17,5 – 22,5	1	1	2	2	3	3
12,5 - 17,5	1	1	2	3	3	4
< 12,5	1	2	3	3	4	5

Legend: PI – ignition frequency (number of positive ignitions out of 50 attempts); MDI – mean time to ignition, in seconds; 0 = no flammability; 1 = low flammability; 2 = moderately flammable; 3 = flammable; 4 = highly flammable; 5 = extremely flammable

The comparison between the moisture content, time to ignition and combustion period means were performed using ANOVA and the Student-Newman-Keuls (SNK) comparison of means test.

Results

Table 2 shows the mean values of the flammability variables for the species studied. There was a large variation between the moisture content (U%) means of the species studied. *M. grandiflora* had the lowest value, while *M. champaca* showed the highest mean moisture content value of the material analyzed. The moisture content of live vegetation varies according to its developmental stage. The characteristics of leaf and branch structures also influence the moisture content of species. The moisture content of vegetation is one of the most important properties that control the flammability of living and dead fuels.

Table 2— Mean values of the flammability variables for the species studied.

Species	U%	MCP	FL	MTI	FV
<i>Viburnum odoratissimum</i>	163,1bc*	4,74 a	10,64 b	18,2	2
<i>Michelia champaca</i>	183,7 c	3,87 a	8,16 a	13,1	3
<i>Magnolia grandiflora</i>	116,8 a	7,44 b	25,22 d	12,5	4
<i>Caseariasilvestris</i>	164,5bc	5,32 a	13,46 c	15,7	4
<i>Jasminum mesnyi</i>	179,1 c	18,53 c	13,92 c	10,9	5

Legend: U% - moisture content of the material in %; MCP – mean combustion period, in seconds; MTI – mean time to ignition, in seconds; FL – flame length, in cm; FV – flammability value.

* Means followed by the same letter in a column do not differ according to the SNK test at 95% level of significance.

The combustion period means presented no great variation among the species tested. Only the species *J. mesnyi* stood out from the others, presenting a mean combustion period approximately 3 times greater than the other species.

The variable flame length (FL) showed a significant difference among most of the species studied. This variable reflects fire intensity, that is, the greater the flame spread, the greater the amount of energy released. The species *M. grandiflora* had the highest FL average and *Michelia champaca* the lowest.

The flammability (FV) of the species tested varied depending on the mean time to ignition (MTI) and its frequency (IP), according to Table 1.

The species with the lowest FV values also have the lowest MCP and FL values.

Discussion

According to the results in Table 2, *J. mesnyi* is the species with the highest level of flammability, i.e., it is extremely flammable, while *C. silvestris* and *M. grandiflora* are highly flammable. The species *Michelia champaca* and *Viburnum odoratissimum* had the lowest flammability values and based on the methodology described by Valette (1990), they were classified as flammable and moderately flammable, respectively.

The flammability of a plant depends on the type, tissue quality and water content in leaves and branches. Species having low moisture contents are expected to have greater flammability (Petriccione 2006). Contrary to such expectations, Figure 1 shows that there is no correlation between the moisture contents of the species and flammability.

Very similar results were found by Petriccione (2006) when evaluating the flammability of various plant species of Italy. While several researchers emphasize the influence of moisture on the flammability of vegetation (Delabrazze and Valette 1982, Soares and Batista 2007), the results of the analyzes performed in this study

did not verify that assertion. There is a need for more detailed studies on other relevant aspects related to flammability, like the presence of volatile organic compounds such as oils, resins and gums in plants, which were not investigated in this work.

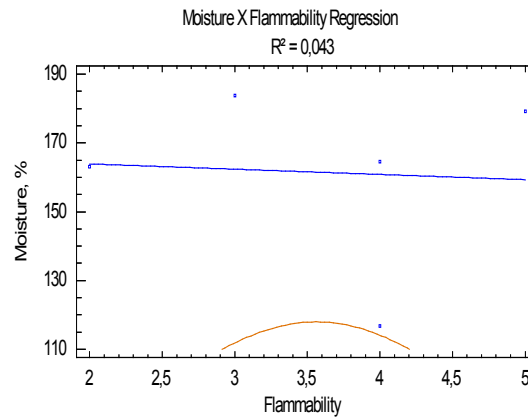


Figure 1—Correlation between the moisture content (%) of the leaves and branches of the species studied and flammability.

By contrast, significant correlations were obtained between other combustion parameters and moisture content, demonstrating the importance of moisture in the vegetation on fire ignition and spread, as seen in Figures 2 and 3.

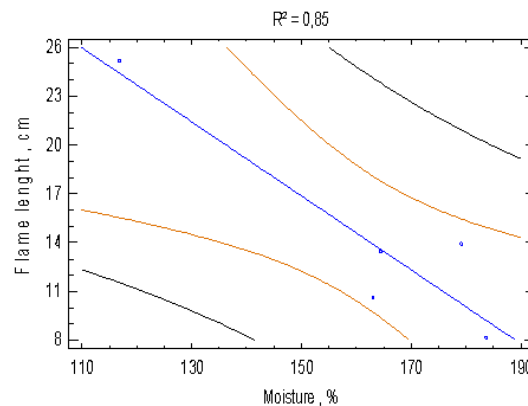


Figure 2—Influence of the moisture in vegetation on flame length (FL).

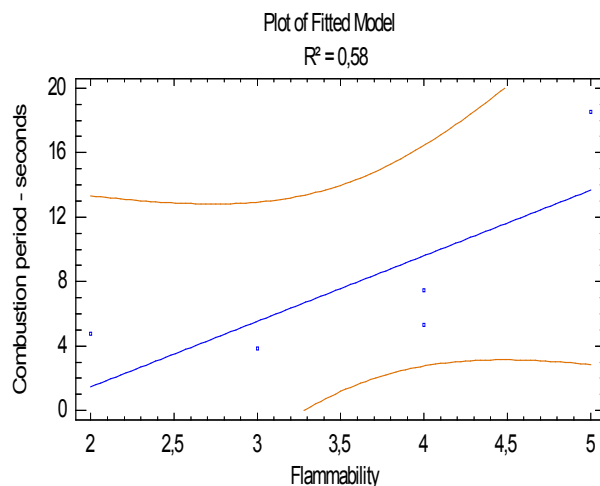


Figure 3—Influence of the moisture in vegetation on combustion (MCP)

Based on the results observed in these preliminary experiments, it can be concluded that the flammability of vegetation varies widely, depending not only on the moisture content but also on the chemical characteristics of the plant structure. These analyzes will be the subject of future research on the flammability issue. Another important conclusion obtained was the feasibility of using the method proposed by Valette (1990) for assessing the flammability of vegetation.

Summary

This paper describes an experiment conducted to investigate the flammability of trees and shrubs used in the establishment of green barriers in the rural-urban interface in the southern region of Brazil. A flammability assessment method which is widely used in several European countries and in the United States was employed. The species evaluated were: *Magnolia grandiflora* L., *Michelia champaca* L., *Jasminum mesnyi* Hance, *Casearia sylvestris* Sw. and *Viburnum odoratissimum* Ker

Gawl. The species *J. mesnyi* had the highest level of flammability, i.e., it is extremely flammable, while *C. silvestris* and *M. grandiflora* are highly flammable. The species *Michelia champaca* and *Viburnum odoratissimum* showed the lowest flammability values and based on the methodology described by Valette (1990), they were classified as flammable and moderately flammable, respectively.

References

- Batista, A. C.; Soares, R. V.** 2008. Silvicultura preventiva - uma alternativa para o controle de incêndios em reflorestamentos. In: I Encontro Brasileiro de Silvicultura, 2008, Curitiba - PR. Anais do Encontro Brasileiro de Silvicultura. Piracicaba: v. 1. p. 199-208.
- Biondi, D.** 2002. Seleção de espécies para o paisagismo rodoviário. Curitiba: FUPEF. Série Técnica. 11p.
- Biondi, D.; Batista, A. C.** 2010. Ornamental plant species of Brazil and their potential use as fire breaks. In: VI International Conference on Forest Fire Research, 2010, Coimbra. Abstracts - VI International Conference on Forest Fire Research - CD-ROM. Coimbra - Portugal : ADAI/CEIF - Ed. Domingos X. Viegas, 2010. v. 1. p. 1-8.
- Carvalho, P. E. R.** 2006. Espécies arbóreas brasileiras. Brasília: Embrapa Informação Tecnológica; Colombo, PR: Embrapa Florestas; 627p.
- Delabraze, P.; Valette, J. C.** 1982. The Use of Fire in Silviculture. Symposium on Dynamics and Management of Mediterranean-type Ecosystems June 22-26, 1981, San Diego, California. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture.
- FPIInnovations, Wildland Fire Operations Research Group. Alberta, Canada.** 2009. Fuelbreak effectiveness: state of the knowledge. In: <http://fire.feric.ca/36532008/FuelBreakLiteratureSummary.pdf> (acesso em 20/07/2009).
- Green, L.R.** 1977. Fuelbreaks and other fuel modification for wildland fire control. USDA Agriculture Handbook, 499.
- Lorenzi, H.** 1992. Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil. Nova Odessa: Plantarum; 315p.
- Lorenzi, H.** 1998. Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil. Nova Odessa: Plantarum; v. 2. 376 p.
- Lorenzi, H.; Souza, H. M.** 2001. Plantas ornamentais no Brasil: arbustivas, herbáceas e trepadeiras. 3. ed. Nova Odessa: Instituto Plantarum; 1088 p.
- Lorenzi, H.; Souza, H. M.; Torres, M. A.; Bacher, L. B.** 2003. Árvores exóticas no Brasil: madeiras, ornamentais e aromáticas. Nova Odessa: Instituto Plantarum; 368 p.
- Petriccione, M.** 2006. Infiammabilità della lettiera di iverse specie vegetali di ambiente Mediterraneo. Università Degli Studi Di Napoli Federico II, Dipartimento di Biologia Strutturale e Funzionale, 48 p. (Tesi Di Dottorato In Biologia Applicata)

- Petriccione, M.; Moro, C.; Rutigliano, F. A.** 2006. Preliminary studies on litter flammability in Mediterranean regions. In: International Conference on Forest Fire Research, 5, Figueira da Foz, Portugal. Proceedings of... [S.I.: s.n.] 6p.
- Ribeiro, G. A.; Lima, G. S.; Oliveira, A. L. S.; Camargos, V. L.** 2007 (in press). Uso de vegetação como aceiro verde na redução da propagação de fogo sob linhas de transmissão. Revista CERES, UFV.
- Tian, X. R.; Shu, I. F.; Wang, M. Y.** 2007. Study on Eight Tree Species' Combustibility and Fuelbreak Effectiveness; In: IV International Wildland Fire Conference, 2007, Sevilla - España. Actas de La IV Conferencia Internacional sobre Incendios Forestales. Madrid - España: Organismo Autónomo de Parques Nacionales, Ministerio de Medio Ambiente, v. 1. p. 1-11.
- Valette J. C.** 1990. Inflammabilités des espèces forestières méditerranéennes. Rev. Forest. Fr. 42, 76-92.
- Vélez, R.** 2000. La defensa contra Incendios Forestales. Fundamentos y experiencias. Madrid: McGraw Hill.