Review

Current Status and Prospects of Plant Flammability Measurements

Minting Jian 1,2,3,†, Yi Jian 4,5,†, Hong Zeng 1,2,3, Dongyu Cao 1,2,3 and Xinglei Cui 1,2,3,*

1 National Forestry and Grassland Administration Engineering Research Centre for Southwest Forest and Grassland Fire Ecological Prevention, College of Forestry, Sichuan Agricultural University, Chengdu 611130, China; mintingjian@stu.sicau.edu.cn (M.J.); hongzeng@sicau.edu.cn (H.Z.); dongyu.cao@sicau.edu.cn (D.C.)
2 National Forestry and Grassland Administration Key Laboratory of Forest Resources Conservation and Ecological Safety on the Upper Reaches of the Yangtze River, Chengdu 611130, China
3 Forestry Ecological Engineering in the Upper Reaches of the Yangtze River Key Laboratory of Sichuan Province, Chengdu 611130, China
4 Ecological Restoration and Conservation for Forest and Wetland Key Laboratory of Sichuan Province, Sichuan Academy of Forestry, Chengdu 610081, China; yi.jian@sclky.com
5 Sichuan Longmenshan National Positioning Observation and Research Station for Forest Ecosystem, Mianyang 622550, China
* Correspondence: xinglei.cui@sicau.edu.cn
† These authors contributed equally to this work.

Abstract: In recent years, the frequency of wildfires worldwide has been gradually increasing, posing significant threats to global ecosystems and human society. Given that plants serve as the primary fuel in natural environments, accurately assessing the flammability of plants is crucial for wildfire management and fire ecology studies. Plant flammability is a multifaceted trait influenced by various physiological, physical, and chemical characteristics of plants. Currently, there is no universally accepted standard for quantifying plant flammability. By analyzing published research over the past few decades, this study found that 17.27% of studies assessed plant flammability by measuring flammability-related characteristics, such as moisture content, leaf size, bark thickness, oil content, and terpene content; a total of 34.55% of studies assessed plant flammability through burning experiments by measuring burning parameters, such as ignition time, duration of combustion, and flame spread rate. The remaining studies, approximately 50%, used a combination of burning experiments and flammability-related characteristic measurement to assess plant flammability. This study outlined the current status of plant flammability measurements, discussed the merits of each measurement method, and proposed suggestions for enhancing the assessment of plant flammability, with the aim of contributing to the standardization of plant flammability measurements.

Keywords: plant flammability; wildfires; measurement methods

1. Introduction

Wildfire is an important ecological factor that serves as a driving force for species diversity and plays a significant role in ecosystem stability [1,2]. For example, fire is likely to have greatly influenced the evolution and proliferation of angiosperms [3]. Under the influence of fire, plant species developed various fire adaptations, such as thicker bark, self-pruning, and serotiny, to adapt to specific fire regimes [4–7]. However, wildfires can develop into sudden, severe, and highly damaging natural disasters that are challenging to extinguish. Under changing climate conditions, the frequency of wildfires is increasing in many regions worldwide [8]. Wildfire has become a rising global problem, threatening public safety, biodiversity, and the stability of many ecosystems.

Plants serve as the primary fuel in nature, and their flammability characteristics directly influence the ease of fire ignition and fire behavior, such as fire spread speed and fire intensity [9,10]. Moreover, plant flammability is an important property that affects plant
survival and reproduction in fire-prone environments [5–7,11]. Consequently, accurately assessing the flammability of various plant species is not only crucial for fire prevention, fire risk assessment, and fire behavior prediction, but is also an important aspect of fire ecology studies [12,13].

Plant flammability has four components—ignitability (the ease of ignition), combustibility (the strength of plant combustion), sustainability (the duration of plant burning), and consumption (the amount of plant burned) [14–17]. These flammability components vary substantially across different species [18–20] and are influenced by multiple plant traits, including plant physiological, morphological, and chemical characteristics [21–24]. For example, moisture content is one of the most frequently reported flammability-related traits that is directly related to flammability components. For both live and dead fuels, the moisture content is influenced by many factors, such as time, climate, and geographical location [25,26]. Litter with a moisture content exceeding 35% has been proven to be challenging to ignite, whereas ignition is facilitated when the moisture content is below 10% [27]. Chemical characteristics, such as phenol content, terpene content, lignin content, cellulose content, and tannin content, also affect plant flammability [28–33]. The content of lignin and tannin in leaves has been found to be positively correlated with the duration of burning [21,28,32,34]. Volatile organic compounds are highly correlated with the flammability of plants. Foliage structure and morphological characteristics, including leaf size, leaf curliness, and litter bulk density, are also important factors that affect plant flammability [35–39]. For instance, the size and shape of leaves may indirectly influence the burning intensity of litter through their impact on fuel bed-scale properties such as depth, bulk density, porosity, or permeability [34,40]. Smaller leaves typically exhibit a high propensity for burning due to the rapid evaporation of moisture, and species with highly curled leaves can accelerate the spread of fire on the fuel bed [41–43].

Currently, there is no universally accepted standard for quantifying plant flammability [12]. The accurate and comprehensive assessment of plant flammability remains a challenge. In this study, we compiled published research on plant flammability measurements and summarized the methods employed in these studies. Our objective was to present the current status of plant flammability measurements and to contribute to the standardization of these measurements.

2. Materials and Methods

2.1. Data Collection

We conducted searches on ‘Web of Science’ and ‘Google Scholar’ using keywords such as ‘plant flammability’, ‘vegetation flammability’, ‘fuel flammability’, ‘forest fuel’, and ‘plant combustibility’ to retrieve relevant articles. Information including the publication date, study area, methods, and variables used to assess plant flammability, as well as the experimental materials, was collected from these articles. We included articles containing experimental data on plant flammability, while excluded database and review articles. From each study, we further extracted details about the experimental method, country, research area, variables measured, material, and publication year. The methodology does entail certain limitations, as it is possible that a few pertinent articles may not incorporate these precise keywords, thereby potentially resulting in some exclusions. Nonetheless, this approach can still manage to capture the bulk of the relevant literature. This comprehensive data collection aimed to provide a thorough understanding of the current methods and variables used in plant flammability measurements, ultimately contributing to the standardization and improvement of these assessment techniques (Supplementary Materials File S1).

2.2. Data Analysis

The collected data were sorted and organized in Excel 2016 (Supplementary Materials File S1). The statistical quantities were classified according to various categories, including year of publication, study area, country, measurement method, material, measured flamma-
bility variables, and measured physiological, physical, and chemical indices of flammability. Charts were generated using Origin 2018 software, while the global distribution of studies on plant flammability measurements was mapped using the Terra (1-7.29) package within R software 4.3.1. This thorough classification and visualization of data aimed to provide a comprehensive overview of the research landscape and highlight key trends and gaps in the study of plant flammability.

3. Results

3.1. Overview of Articles on Plant Flammability Measurements

A total of 220 articles related to plant flammability measurements were retrieved from the Web of Science and Google Scholar databases (Supplementary Materials File S1) [14–24,27,28,30,31,33–230]. The earliest research related to plant flammability measurement was published in 1964 [205]. By 1970, researchers began to focus on the relationship between plant functional traits and flammability [202]. Over the years, the number of published papers has steadily increased, with a significant surge after 2008 (Figure 1).

![Figure 1](image)

**Figure 1.** The number of public articles in recent decades on the plant flammability measurements (1964–2022).

The research areas of these studies were mainly concentrated in the United States of America (28.19%), China (12.33%), and Australia (13.22%). Articles from these three countries collectively accounted for approximately half of the total worldwide publications. This was followed by France (6.61%), Spain (5.29%), Argentina (4.41%), and New Zealand (3.96%) (Figures 2 and 3). Additionally, we examined articles originating from the Mediterranean climate (MTC) region. The Mediterranean climate region is characterized by strong seasonality, featuring hot, dry summers and mild, wet winters [95,122], which contributes to the frequent occurrence of wildfires in this region [48]. A total of 40 articles were found that were conducted in the Mediterranean climate region, accounting for 20.51% of worldwide studies (Figure 2).

3.2. Methods for Plant Flammability Measurements

Methods for plant flammability measurements can be broadly categorized into the following three types: (1) measuring flammability-related characteristics, (2) burning experiments, and (3) a combination of burning experiments with flammability-related characteristic measurements. The method that integrates burning experiments with flammability-related characteristic measurements is the most commonly used, comprising approximately 50% of the methods employed in these studies. Methods that assess flammability by measuring flammability-related characteristics account for 17.27%, while burning experiments make up 34.55% (Figure 4).
Figure 2. Distribution of public papers related to plant flammability measurements. The red dots represent the study sites of plant flammability measurements; the blue area represents the Mediterranean climate region.

Figure 3. Percentage of countries where articles on plant flammability measurements have been published.

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3.2.1. Burning Experiments

In burning experiments, leaves and litter are the most commonly used materials, accounting for 30.65% and 25.70%, respectively. These are followed by shoots (17.96%) [17,19,46–49], barks (4.02%) [18,20,62,104,152,189], and others (21.67%) [57,71,112,118,170,212,231,232] (Figure 5). Four flammability components, namely ignitability, combustibility, sustainability, and consumption, were measured in 6.36% of studies. More than 50% of the studies used two or three flammability components to evaluate plant flammability. Around 10% of studies only used one flammability component, either ignitability (7.27%), combustibility (4.55%), or sustainability (1.00%) (Figure 6).
Flammability components were evaluated by using different burning variables (Figure 7; Table 1). Ignition time and rate of spread are commonly used to assess ignitability [14,15,17]. Specifically, 65.13% of studies used ignition time, 20.41% used rate of spread, and 14.29% used both ignition time and rate of spread. Combustibility is typically assessed using maximum flame temperature, maximum flame height, and peak heat release rate [15,66,71]. In detail, 35.21% of studies used maximum flame height, 30.28% used maximum flame temperature, 15.49% used peak heat release rate, 11.27% used both maximum flame height and maximum flame temperature, 5.63% used both maximum flame temperature and peak heat release rate, and 2.11% used both maximum flame height and peak heat release rate. Sustainability is evaluated using the flame duration and effective heat of combustion. Among the studies, 87.13% used flame duration, 7.92% used the effective heat of combustion, and 4.95% used both flame duration and the effective heat of combustion. Consumability was reflected solely by the residual mass fraction.
Figure 5. Percentage of tested materials for plant flammability measurements.

Figure 6. Percentage of flammability components used in published papers for plant flammability measurements.

Figure 7. Percentage of burning variables for plant flammability components measurements (TTI is defined as ignition time; ROS is defined as rate of spread; HRR is defined as peak heat release rate; MT is defined as flame temperature; MH is defined as flame height; FD is defined as flaming duration; EHC is defined as effective heat of combustion; RMF is defined as residual mass fraction).

Table 1. Description of the main indexes for determination of flammability components of plants.

<table>
<thead>
<tr>
<th>Flammability Components Measured Variables</th>
<th>Unit Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignitability</td>
<td></td>
</tr>
<tr>
<td>Ignition time (TTI)</td>
<td>s</td>
</tr>
<tr>
<td>Rate of spread (ROS)</td>
<td>mm min⁻¹</td>
</tr>
<tr>
<td>Combustibility</td>
<td></td>
</tr>
<tr>
<td>Flame height (FH)</td>
<td>cm</td>
</tr>
<tr>
<td>Flame temperature (FT)</td>
<td>°C</td>
</tr>
<tr>
<td>Peak heat release rate (HRR)</td>
<td>kW/m²</td>
</tr>
<tr>
<td>Sustainability</td>
<td></td>
</tr>
<tr>
<td>Flaming duration (FD)</td>
<td>s</td>
</tr>
<tr>
<td>Effective heat of combustion (EHC)</td>
<td>MJ/kg</td>
</tr>
<tr>
<td>Consumability</td>
<td></td>
</tr>
<tr>
<td>Residual mass fraction (RMF)</td>
<td>%</td>
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</tbody>
</table>

3.2.2. Flammability-Related Characteristic Measurements

Assessing flammability through the measurement of plant physiological and physicochemical characteristics is feasible, as plant flammability is strongly correlated with these characteristics. Understanding these characteristics, such as moisture content, leaf size, oil content, etc., can provide valuable insights into plant flammability [28,36,91,156]. It is important to note that these flammability-related characteristics are associated with flammability, but do not establish a causal relationship.
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</thead>
<tbody>
<tr>
<td>Ignitability (46.82%)</td>
<td>Ignition time (TTI)</td>
<td>s</td>
<td>The time elapsed from the application of the ignition source to the appearance of the flame</td>
</tr>
<tr>
<td></td>
<td>Rate of spread (ROS)</td>
<td>mm min⁻¹</td>
<td>Speed of flame spread during combustion</td>
</tr>
<tr>
<td>Combustibility (50.00%)</td>
<td>Flame height (FH)</td>
<td>cm</td>
<td>The maximum height of the flame when burning</td>
</tr>
<tr>
<td></td>
<td>Flame temperature (FT)</td>
<td>°C</td>
<td>The maximum temperature at which a fuel burns</td>
</tr>
<tr>
<td></td>
<td>Peak heat release rate (HRR)</td>
<td>kW/m²</td>
<td>The maximum value of the velocity of energy release</td>
</tr>
<tr>
<td>Sustainability (44.45%)</td>
<td>Flaming duration (FD)</td>
<td>s</td>
<td>The duration of the flame when burning</td>
</tr>
<tr>
<td></td>
<td>Effective heat of combustion (EHC)</td>
<td>MJ/kg</td>
<td>The amount of energy released at a pointed time, normalized by the initial sample mass k</td>
</tr>
<tr>
<td>Consumability (20.45%)</td>
<td>Residual mass fraction (RMF)</td>
<td>%</td>
<td>The percentage of fuel remaining after combustion</td>
</tr>
</tbody>
</table>

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More than half of the studies measured physiological characteristics, with 63.64% focusing on this aspect, and moisture content is the most commonly assessed trait. Physical characteristics were examined in half of the studies, with leaf size, leaf texture, and leaf thickness being the three most frequently measured traits. When evaluating the flammability of litter, packing density, packing ratio, leaf surface area-to-volume ratio, and fuel area-to-volume ratio were the most commonly used physical characteristics [41,82,83]. Approximately one-third of the studies utilized chemical compositions to assess plant flammability. These chemical compositions primarily included variables such as terpene content, lignin content, oil content, cellulose content, tannin concentration, carbon content, nitrogen content, phosphorus content, and other chemical elements (Figure 8) [28,54,60,70]. Among these, cellulose, oil, and terpene content were the most commonly measured chemical components (Supplementary Materials File S1).

![Figure 8. Percentage of physiological and physicochemical characteristics used for plant flammability measurements.](image-url)
4. Discussion

Evaluating plant flammability by measuring flammability-related characteristics is a common approach in previous studies. However, plant flammability is a complex property with multiple components, and these components are influenced by various plant traits, including physiological characteristics, morphological features, and chemical composition [43,205,223,226,227]. For example, Popović and Zorica [233] found that physical and chemical characteristics such as specific leaf area, leaf thickness, litter bulk density, and leaf terpenoid content have strong relationships with flammability components. Some characteristics may influence the flammability of different organs distinctly. For instance, plants with smaller leaves may produce densely packed litter, which could result in oxygen deficiency and subsequently reduce burning rates. Conversely, smaller leaves may enhance shoot-level flammability [41–43]. Physiological changes also affect plant flammability, such as characteristics related to the water and carbon cycles [234]. Moreover, the primary determinants of flammability may vary across species. Therefore, measuring specific plant characteristics for flammability assessment may not fully capture the true flammability of plants in natural settings.

Burning experiments represent another approach for assessing the flammability of plants. These experiments provide a more direct evaluation of plant flammability components compared to measuring flammability-related traits. Burning entire plants can offer a comprehensive reflection of their flammability, but this method is highly challenging and costly, especially for trees and large shrubs [13,228,235]. As a result, researchers often opt to assess plant flammability by burning different plant parts. For instance, leaves (30.13%) and litter (25.63%) (Figure 5) are the most frequently used materials in burning experiments, comprising half of the experiments (Figure 4). Leaves and litter are favored due to their ease of collection and suitability for burning in equipment like cone calorimeters, surface radiometers, or Muffle furnaces. However, the flammability characteristics of small plant parts may not accurately represent those of the entire plant, and significant variations in flammability can exist among different plant organs [37,92,228,236]. Therefore, it is crucial to select appropriate plant parts when conducting burning experiments. Woody litter and entire grasses/forbs are suitable for assessing plant flammability in surface fires, while woody branch material may be more appropriate for evaluating flammability during crown fires, as they serve as primary fuels for surface and crown fires, respectively [1,237–239].

However, there is currently no universally accepted standard method or instrument for conducting burning experiments. Although ignitability, combustibility, sustainability, and consumability are widely accepted as the main burning components [235,240], most studies did not utilize all the four components to assess plant flammability. The burning variables being used to reflect these flammability components also differ among studies. For example, ignition time, ignition frequency, and ignition point are commonly used to assess ignitability. The flaming time and effective heat of combustion are employed to gauge sustainability. However, the optimal variable to accurately measure each flammability component remains ambiguous. Furthermore, different experimental setups, such as varying ignition sources, can significantly influence experimental outcomes [241,242]. How samples are placed also plays a critical role in burning experiments. For instance, burning stacked shoots typically prolongs the ignition time compared to hanging them down, due to increased shoot density reduced the airflow [41,72,82,243]. The lack of standardization in burning experiments has led to disparate results among researchers, hindering advancements in plant flammability research [235,240,244].

Laboratory studies on plant flammability have limitations in capturing the complexity of factors present in natural conditions, which restricts our ability to accurately assess the flammability of a particular species in natural environments [240]. When measuring plant flammability, it is crucial to consider natural conditions such as wildfire conditions and macroclimate conditions [9,137,235,245]. Moreover, the sample collection time is also an important factor that needs to be considered. For instance, different collection times can significantly affect plants’ physiological characteristics, thus effecting plant flammability [235].
To ensure consistency, some researchers recommend measuring plant flammability during fire seasons. Additionally, the transportation and storage of experimental materials can result in the loss of moisture content. Consequently, conducting burning experiments effectively and scientifically remains a challenge and requires further studies. The standardization of plant flammability measurements may be the first step in better assessing plant flammability and predicting the likelihood of fires in a given area.

Plant flammability studies will inform wildfire management. Identification and plantation of low-flammability species can help mitigate fire risk and impede wildfire spread [246]. For example, the construction of green firebreaks is a promising approach to mitigate wildfires [28,31,64]. In high-risk areas, removing or reducing highly flammable species like those from the *Pinus*, *Quercus*, and certain *Eucalyptus* species can reduce the fire risk [162,247–249]. Investigation into the effect of moisture content on litter flammability can help counteract the effects of drought with timely and effective measures [250–252]. Using plant flammability research data, wildfire risks in specific species distribution areas can be better assessed, guiding fire preventive measures.

5. Conclusions

Accurately assessing the flammability of various plant species is crucial for wildfire management and fire ecology studies. The current mainstream methods for plant flammability measurements include (1) measuring flammability-related characteristics, (2) burning experiments, and (3) a combination of burning experiments with flammability-related characteristic measurements. However, the flammability-related characteristics and burning variables used differ across studies. Furthermore, it is uncertain whether assessing plant flammability solely based on flammability-related characteristics accurately reflects the real flammability of the plants. Burning experiments are likely to provide a better reflection of plant behavior during combustion, but the choice of plant parts and the burning equipment used are inconsistent across studies. These inconsistencies have resulted in incomparable results among different researchers, impeding progress in plant flammability research. Therefore, there is still much work to be conducted in relation to improving the assessment of plant flammability and standardizing measurement methods. Establishing universally accepted protocols and methodologies will be key to advancing our understanding of plant flammability and enhancing wildfire management strategies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fire7080266/s1, Supplementary Materials File S1.

Author Contributions: M.J.: Conceptualization, Formal analysis, Writing—original draft; Y.J.: Formal analysis and Methodology; H.Z.: Supervision and Writing—editing; D.C.: Writing—editing; X.C.: Conceptualization, Funding acquisition, Writing—review and editing, and Supervision. All authors have read and agreed to the published version of the manuscript.

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References


40. Ganteaume, A.; Jappiot, M.; Curt, T.; Lampin, C.; Borgniet, L. Flammability of Litter Sampled According to Two Different Methods: Comparison of Results in Laboratory Experiments. *Int. J. Wildland Fire* 2014, 23, 1061–1075. [CrossRef]


45. Yang, W.; Bakar, B.H.A.; Mamat, H.; Gong, L.; Nursyamsi, N. A Laboratory-Scale Study of Selected Chinese Typical Flammable Wildland Timbers Ignition Formation Mechanism. *Fire* 2023, 6, 20. [CrossRef]


57. Chen, F.; Si, L.; Zhao, F.; Wang, M. Volatile Oil in *Pinus yunnanensis* Potentially Contributes to Extreme Fire Behavior. *Fire* 2023, 6, 113. [CrossRef]


Romero, B.; Ganteaume, A. Effect of Fire Frequency on the Flammability of Two Mediterranean Pines: Link with Needle Terpene Content. *Plants* 2021, 10, 2164. [CrossRef]  
Scarff, R.F.; Gray, B.F.; Westoby, M. Exploring Phosphate Effects on Leaf Flammability Using a Physical Chemistry Model. *Int. J. Wildland Fire* 2012, 21, 1042–1051. [CrossRef]  

146. Fraser, I.P.; Williams, R.J.; Murphy, B.P.; Camac, J.S.; Vesn, P.A. Fuels and Landscape Flammability in an Australian Alpine Environment. *Austral Ecol.* **2016**, *41*, 657–670. [CrossRef]


152. Cui, X. Intraspecific Variation in Shoot Flammability in Dracophyllum Rosmarinifolium Is Not Predicted by Habitat Environmental Conditions. *For. Ecosyst.* **2022**, *9*, 100017. [CrossRef]


198. Vila, A.; Grootemaat, S.; Leishman, M.R. Leaf Flammability and Fuel Load Increase under Elevated CO2 Levels in a Model Grassland. Int. J. Wildland Fire 2015, 24, 819. [CrossRef]


201. White, A.S. The Effects of Thirteen Years of Annual Prescribed Burning on a Quercus Ellipsoidalis Community in Minnesota. Ecology 1983, 64, 1081–1085. [CrossRef]

206. Ulok, G. Fuel Characteristics of Selected Plant Species Regrow on Burn Area in Raja Musa Forest Reserve; School of Graduate Studies, Universiti Putra Malaysia: Selangor, Malaysia, 2015.
227. Pickett, B.M.; Jackson, C.; Wunder, R.; Fletcher, T.H.; Butler, B.W.; Weise, D.R. Flame Interactions and Burning Characteristics of Two Live Leaf Samples. Int. J. Wildland Fire 2009, 18, 865. [CrossRef]
228. Gill, A.M.; Moore, P.H.R. Ignitibility of Leaves of Australian Plants; CSIRO: Canberra, Australia, 1996.
238. van Wagendonk, J.W.; Moore, P.E. Fuel Deposition Rates of Montane and Subalpine Conifers in the Central Sierra Nevada, California, USA. For. Ecol. Manag. 2010, 259, 2122–2132. [CrossRef]
242. Cawson, J.G.; Burton, J.E.; Pickering, B.J.; Demetriou, V.; Filkov, A.I. Quantifying the Flammability of Living Plants at the Branch Scale: Which Metrics to Use? Int. J. Wildland Fire 2023, 32, 1404–1421. [CrossRef]
244. Papió, C.; Trabaud, L. Comparative Study of the Aerial Structure of Five Shrubs of Mediterranean Shrublands. For. Sci. 1991, 37, 146–159. [CrossRef]