

Article

Flammability and Reaction to Fire of Different Plant Species Intended as Vertical Greenery on Building Façades

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Abstract: Vertical greenery or green walls are spreading rapidly not only in Southeast Asia but also in colder regions such as Western and Central Europe. The simultaneous growth and densification of larger cities has accelerated this trend recently as these cities require increased green space to improve living quality. A significant issue directly affecting security aspects regarding building components covered with different kinds of plants is their fire behaviour. A major parameter expected to influence this behaviour is the moisture content of the plants and their ability to retain moisture in case of irrigation interruption. In this study, four different plant species were chosen due to their hardiness which favours their usage as vertical greenery under the climatic conditions of Central Europe. Bomb and cone calorimetric investigations and single-flame source tests were carried out on them. These tests have been executed at different plant moisture contents as the fire behaviour of plants is obviously influenced by their moisture content. The results quantify the remarkable individuality of the plants with respect to their reaction to fire exposure in both moist and dry conditions. The findings can be extrapolated to quantify the overall fire behaviour of a green façade, especially the accruing heat content. Additionally, an optimized position of different plants within the façade can be derived to reduce the flame propagation probability upward of the façade.

Keywords: fire behaviour; heat of combustion; vertical greenery; green façade; moisture content; bomb calorimetry; cone calorimetry; single-flame source



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1. Introduction

Vertical greenery, green walls, or living wall systems as they are called have seen a remarkable boost in the building industry worldwide due to the double trend of “growing and densifying” of large cities. The topic of “vertical greenery” relates to an emerging trend in architecture towards the inclusion and integration of vegetation into façades. Vertical greenery in urban, commercial, and private areas offers creative and climatically relevant advantages for existing and new buildings [1]. A state-of-the-art dating back to 2017 [2] provides a definition which states that green walls are divided into two main categories: green façade and living wall. The former uses climbing plants with or without an additional support system, and the latter has plants scattered throughout the wall. There are two types of living walls: hydroponic or soil-cell system. The authors address all criticisms brought up against living walls in depth but do not mention their reaction to fire and conclude that experts predict that the corresponding standards and norms dealing with living walls are still a decade away, and the topic remains a testing ground rampant with innovation [2]. Complementarily, the aesthetical aspect of greenery on residential buildings has been tackled by White et al. [3]. They surveyed 188 participants and concluded that the right type of vegetation may also help to satisfy human aesthetic feelings and could play an important role in the regeneration of cities in the future. The issue of life cycle analysis has been investigated too, namely by Natarajan et al. [4]. Investigations

regarding the thermal behaviour of vertical greenery have been conducted extensively in the past decade [5–9]. Cheng et al. [10] experimentally showed that vegetated cladding for public housing apartments reduced indoor temperatures and delayed solar heat transfer, which consequently reduced power consumption for air conditioning compared with a bare concrete building envelope. Ottel  et al. [11] measured the temperature differences between bare walls and the different vertical greening systems, up to 1.7  C for the green fa ade system and 8.4  C for the living wall system based on planter boxes after 8 h of heating for summer conditions. A case study of a double-skin green fa ade in Shanghai has been reported by Yang et al. [12] investigating the summertime cooling performance of a double-skin green fa ade of a renovated multi-storey administrative building in a university campus. The initial findings suggest a clear potential for vertical greenery in thermal comfort improvement and cooling energy saving. Li et al. [13] went into the detail of foliage thickness. They focused on the effect of foliage thickness on the thermal performance of green fa ades under hot and humid climates and found an optimum of about 20 cm for the plant species “Boston ivy” for the climatic conditions of Suzhou, China. Tudiwer et al. [14] carried out in situ U-value measurements and numerical simulations on the greened part of a fa ade as well as on the not-greened part of the same fa ade. The comparison of the measured and simulated values showed that the extreme values of the measured values are more pronounced than the simulated ones. Azkorra et al. [15] investigated the contribution of vertical greenery systems to noise reduction, especially a modular-based green wall, by conducting two different standardised laboratory tests. Chew et al. [16] aimed at strengthening the knowledge base on high-rise vertical greenery fa ades in the tropics, leading to the formulation of a case study-based design for maintainability guidelines to assist clients, designers, and contractors. Medl et al. [17] published a review of technologies and research advancements regarding vertical greening systems back in 2017.

Studies dealing with the reaction to fire of such elements are, on the contrary, scarce. The main question here is the propagation of fire from an open or broken window through the fa ade to higher parts of the building. There is a German publication [18] reporting on the current state of research regarding the fire safety evaluation of green fa ades as defined above (climbing plants). The authors concluded that fire protection solutions can be achieved if the correct plant species and construction forms are chosen. A more detailed study dealing with the plants used for vertical greenery systems has been presented by Dahanayake et al. [19]. They studied the ignition, heat release, and gaseous emissions of three different plants with different moisture contents using the cone calorimeter. Recently, Kotzen et al. [20] reported on the fire safety risks of external living walls and implications for regulatory guidance in England. This year, Bielawski et al. [21] explored the impact of moisture content and wind impact on the fire behaviour of modular living walls. Still, there is a large gap regarding the overall influence of plant type, assembly in a wall, and irrigation procedure on vertical greeneries’ reaction to fire and the determination and evaluation of parameters for the comparison of different systems, respectively.

A summary of the mentioned literature has been provided in Table 1.

Table 1. Summary of the mentioned literature on vertical greenery relevant to the present study.

Authors (By Date)	Fa�ade Type	Main Objective	Main Outcome
Cheng et al., 2010 [10]	Living walls	Thermal performance of turf-based planting modules	The cooling effect mediated by transpiration relies on healthy plant cover and adequate irrigation
White et al., 2011 [3]	Both types	Psychology: preferences and perceptions	Not only valuable environmentally, but help to satisfy our human needs for aesthetics and restoration
Susorova et al., 2013 [5]	Both types	Thermal performance	A mathematical model validated with one-week-long experiments on an existing wall

Table 1. Cont.

Authors (By Date)	Façade Type	Main Objective	Main Outcome
Haggag et al., 2014 [6]	Living walls	Experimental study in a hot and arid climate	During daytime in July, on average, a temperature that is 5 °C lower than a bare wall
Azkorra et al., 2015 [15]	Living walls	Acoustic analysis using lab tests	Green walls have significant potential as a sound insulation tool for buildings
Natarajan et al., 2015 [4]	Living walls	Energy and water use, GHG emission, lifetime, payback	Reducing the watering by half reduced the energy use by 46% and the total GHG emissions by 37%
Ottelé et al., 2017 [11]	Both types	Measuring the thermal behaviour in summer and winter	Estimation of an R-value, cooling effect in summer, and reduced heat flux from the wall in winter
Riley 2017 [2]	Living walls	State of the art of living walls, lessons learned	The data produced, irrespective of whether favourable or not, provide an opportunity for the living wall industry
Bianco et al., 2017 [7]	Living walls	Long-term monitoring of thermal behaviour	During summer, the potential in reducing the urban heat island effect was demonstrated
Medl et al., 2017 [17]	Both types	Review on recent technologies and research	Research in the field is well advanced, providing central but still huge potential for development
Dahanayake et al., 2018a [8]	Single plants	Influence of moisture content on ignitability	Risk matrix for three different plants; importance of selecting suitable species
Dahanayake et al., 2018b [19]	Both types	EnergyPlus Simulations for cooling load	Both green roofs and green walls effectively reduce cooling load. Important parameters are area of coverage, orientation, scale of the building, surrounding environment, and geographical location
Yang et al., 2018 [12]	Both types	Thermal and energy performance, case study	Clear potential of VGS in thermal comfort improvement and cooling energy saving
Pfoser 2018 [1]	Both Types	Book: Vertical Greenery, a vade mecum	Extensive information on all aspects concerning vertical greenery on buildings (in German)
Li et al., 2019 [13]	Green Façades	Influence of foliage thickness (canopy) on T and RH	Experimental data on temperature and RH for three different foliage thicknesses
Tudiwer et al., 2019 [14]	Living walls	Simulation model for heat insulating effect	Extreme values of measured values more pronounced than simulation. R increases by 0.26 m ² K/W
Chew et al., 2019 [16]	Both types	Design for maintainability of high-rise façades	Guidelines for design, construction, and maintenance to inhibit prevalent defects in the tropics
Engel et al., 2020 [18]	Green façades	Fire safety evaluation of whole façades	Temperature evolution on different heights of the façades during fire tests
Hoffmann et al., 2021 [9]	Green façade	Modelling the cooling energy saving potential	A 1D model for calculating surface temperatures and heat fluxes between greening and building
Kotzen et al., 2023 [20]	Living walls	Fire safety and regulatory guidance; potential of CFD fire simulation	Full-scale or modified SBI tests are appropriate; importance of maintenance
Bielawski et al., 2024 [21]	Living walls	Investigation of moisture content and wind impact on the fire spread at different scales	The accumulated downfall of the dry substrate exhibited prolonged smoldering combustion that was difficult to contain. Wind has accelerated the combustion of the plants

The present study investigates different plants chosen due to their hardiness (resistance to cold), favouring their usage as vertical greenery under the climatic conditions of Central Europe. Bomb and cone calorimetric investigations, and single-flame source tests, have been carried out to obtain an overall, realistic, and individual picture of their reaction to fire.

2. Materials

There are numerous species of plants different in size, colour, water demand, hardiness, care effort, PH value of the substrate or soil, etc. An extensive overview of 90 plants which can be used for vertical greenery, including the mentioned properties, has been summarized in [1]. For the present investigation, five plant species were selected based on the low water and low care requirements as well as hardiness compatible with the climatic conditions of the Swiss flatlands (excluding mountainous regions). The intention was to have five species differing in their appearance i.e., leaf structure, colour, bushiness, length of leaf, and of course widespread availability in Central Europe at low to moderate costs. Table 2 shows a summary of the features of these plants:

Table 2. The five species of plants chosen for the investigations.

Plant and Abbreviation	Exposure	Potting Soil	Hardiness min. Temp. °C	Height	Appearance
Sagina Subulata SS	Full sun	Sandy and permeable	4 −34.5 to −28.9	3–5 cm	
Scleranthus Uniflorus SU	Sun	Dry and permeable	7 −17.8 to −12.3	5–10 cm	
Festuca Cinerea FC	Full sun	Dry and permeable	6 −23.4 to −17.8	20 cm	
Carex Oshimensis CO	Half-shadow	Moist and permeable	7 −17.8 to −12.3	20–30 cm	
Festuca Gautieri FG	Full sun	Dry and permeable	5 −28.8 to −23.4	15–20 cm	

3. Methods

Three complementary investigative methods have been used to enable an overall view of the behaviour of the investigated plant species when exposed to fire temperatures. In all three methods, the influence of the plant's moisture content was taken into consideration. First, a bomb calorimetric investigation [22] was carried out to determine the combustion heat of each plant. In a second step, cone calorimetry [23] was applied to measure the corresponding time of ignition and heat release rate. Finally, the single-flame source test [24] was used for single plants embedded in thermally inert mineral wool to acquire knowledge of their behaviour upon direct impingement of a flame.

These three methods are not standard methods designed to test plants; therefore, certain alterations in sample preparation and evaluation were unavoidable. Hence, full compliance with the standards was not possible.

3.1. Plant Moisture Content

As mentioned earlier, an essential factor in determining the reaction to fire temperatures is the individual plant moisture content (moist mass/dry mass in %). In particular, how this parameter changes over time after irrigation has stopped. In other words, the fire behaviour at different “drying stages” is vital for the evaluation of the investigated plant species. Sufficient sample material was preconditioned to obtain representative results, and the measurements were carried out in a specifically defined time frame. The plants were taken at regular time intervals after irrigation was stopped, weighed, and dried at 80 °C for 72 h. The difference between the initial (wet) and the final (dry) matter was taken as the moisture content loss and expressed as a percentage of the dry matter for that specific time interval. The plants were placed in a room with ambient conditions without direct solar irradiation on them and the time intervals were chosen in a manner to obtain representative curves with enough precision. The correspondence between real weather data and drying behaviour depends on many other parameters such as solar irradiation, wind, orientation, and driving rain which is a topic of its own and beyond the present study.

3.2. Bomb Calorimetry

A bomb calorimeter is used to measure the heat of combustion, i.e., the energy released by a material when it catches fire. This amount of energy can in turn cause the combustion of other materials in the neighbourhood of the burning material and fuel the fire. In a calorimeter, combustion was carried out under defined conditions. To do this, the decomposition vessel was filled with a weighed fuel sample and burning aids, the fuel sample was ignited, and the temperature increase of the calorimeter (entire system) was measured. The specific calorific value of the sample (energy per mass) was calculated as follows:

$$H_o = (C \times DT - Q_{Ext1} - Q_{Ext2})/m$$

m = weight of fuel sample

C = heat capacity (C-value) of calorimeter system

DT = calculated increase of water temperature in the inner vessel of the measuring cell

Q_{Ext1} = correction value for the heat energy generated by the cotton thread (ignition aid)

Q_{Ext2} = correction value for the heat energy from other burning aids

The used apparatus was an IKA calorimeter system C 200 bomb calorimeter (Figure 1).

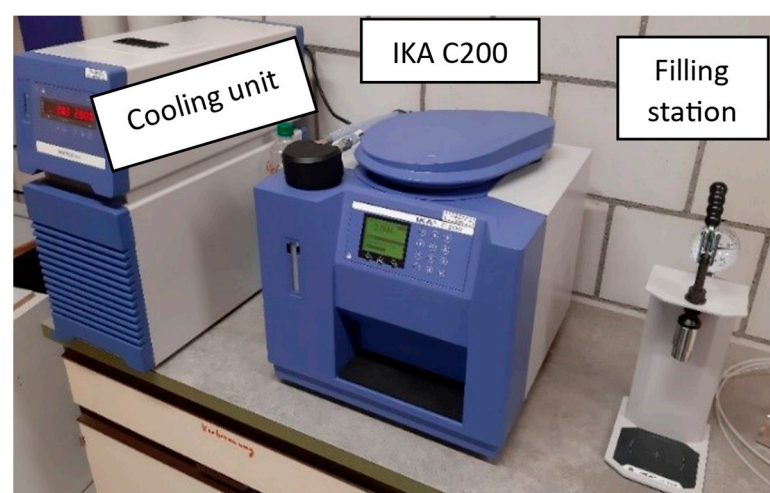


Figure 1. IKA C 200 calorimeter system with cooler and filling station.

In the first step, the volume of the plant sample had to be determined. To do this, parts of the plant were cut off from the conditioned plant and placed in a small plastic bag (Figure 2), the air was pumped out, and the open side was welded shut. The bag was then placed in a 30 mL measuring cylinder and 30 mL of water was added and then the volume

was measured. The density of the sample was determined by using a weighing scale. The sample volume was carried out rapidly after the welding to ensure the plant vapour did not have time to inflate the plastic bag.

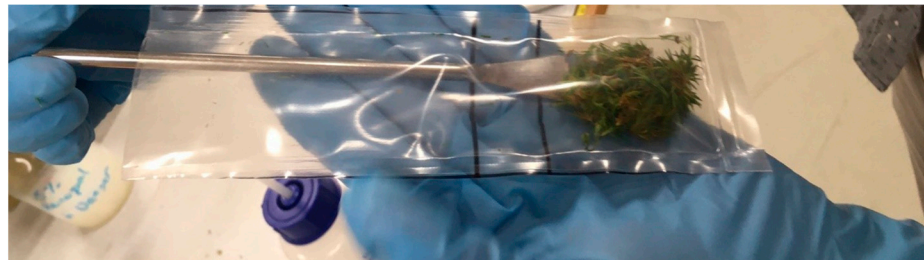


Figure 2. The plant sample is placed in a plastic bag, the air is removed, and the edge of the bag is welded shut. Gloves were used to avoid contamination or falsification of the calorific value.

3.3. Cone Calorimetry

The temporal heat release and the heat release rate of the samples were determined using a “cone calorimeter” test facility according to ISO 5660-1 [23]. The test was carried out with standardized test specimens, which were thermally stressed in horizontal orientation by a heat radiator with a constant radiation intensity above them. A spark igniter was also used. An irradiance of 50 kW/m^2 was used in the following investigations. The principle of cone calorimetry is based on the measurement of the decreasing oxygen concentration in the combustion gases of a sample exposed to a specific heat flux. The apparatus used was a fire testing technology (FTT) Dual Cone Calorimeter Model S/N: 7114966 with methane as the fuel gas (Figure 3). Similar measurements on plants have been conducted by Weise et al. [25], Fateh et al. [26], and Dahanayake et al. [19]. For these measurements, only three plant species out of the aforementioned five were selected. The three species have different behaviours and were chosen due to their advantageous moisture retention behaviour and fire reaction in their respective dry state.



Figure 3. The FTT Dual Cone Calorimeter.

The procedure for the measurement was as follows:

1. Delivery of the three plant species: CO, FG, and SS.
2. Normal watering of the plants (day 0); this is considered as “irrigation stop”.
3. The first measurement (Day 1) of each species by M1 (for cone calorimeter) and M2 (for moisture determination).

4. The second measurement (Day 7) of each species by M1 (for cone calorimeter) and M2 (for moisture determination).
5. The third measurement (Day 16) of each species by M1 (for cone calorimeter) and M2 (for moisture determination).

3.4. Single-Flame Source Tests

These tests were carried out using the Taurus Instruments KBK (Figure 4). The samples consisted of a thermally inert substrate (mineral wool) and plants. The plants were tested in both normal and low moisture conditions.

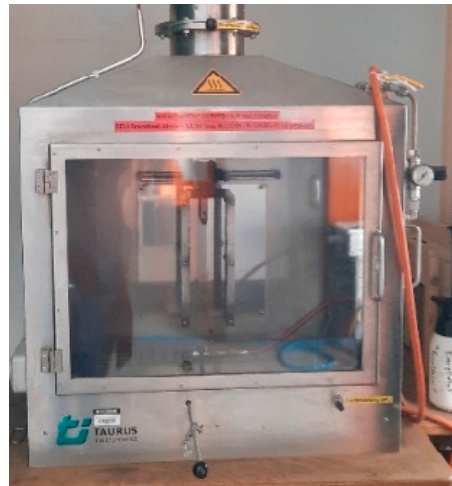


Figure 4. Apparatus for the single-flame source test (KBK Taurus Instruments).

This was performed to ensure the burning behaviour of the samples was assessed in the worst-case scenario of maximum plant drought. The reason why this represents the worst-case scenario is that the heat release rate is expected to be higher when the plants are dry.

According to the prescribed test conditions of ISO 11925-2:2020 [24], each sample was subjected to edge ignition in a small furnace for 30 s. After 30 s of direct exposure to the flame, the burner was removed, and the sample was observed for a further 30 s, after which the test was considered complete. It should be kept in mind that this instrument and the corresponding standard are intended to test regular-shaped insulation and other building materials. The irregular shape of plants obviously does not allow for full compliance with the requirements of the standard.

4. Results

4.1. Moisture Content

In Figure 5, the moisture content of each of the five species is shown as a function of time after irrigation stop. The plant species show clear differences in their temporal behaviour after the irrigation is stopped. Their initial moisture levels are different, and they dry out at different rates. The two species FC and FG kept their moisture content relatively stable for over 10 days. SU reacted more quickly and dried up almost completely after 7 days. After two weeks, however, the moisture contents of the different plants gradually approached a common value.

The plants which were able to keep their moisture content as long as possible after an interruption in irrigation have been considered as more resilient and therefore better suited as vertical greenery on building façades.

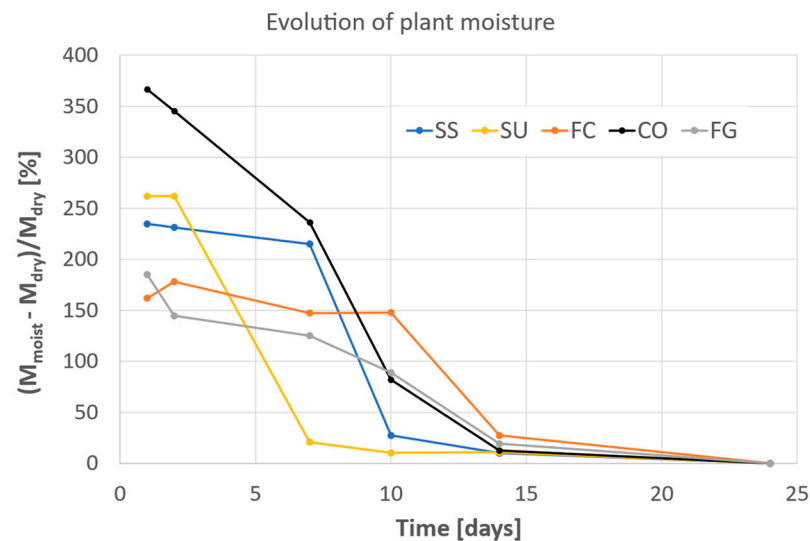


Figure 5. Evolution of the moisture content for the five plant species at regular intervals after irrigation was stopped at time 0.

4.2. Bomb Calorimetry

As expected, the calorific value of the five plant species evolved differently after irrigation was stopped. This is shown in Figure 6, where the species that retained their moisture longer showed a lower increase in calorific value over the first 10 days. This behaviour is advantageous in case of fire incidence. Using this information, three of the plants (CO, FG, and SS) were chosen for further investigation. The species SU cannot retain moisture for sufficiently long and the species FC is too similar to FG.

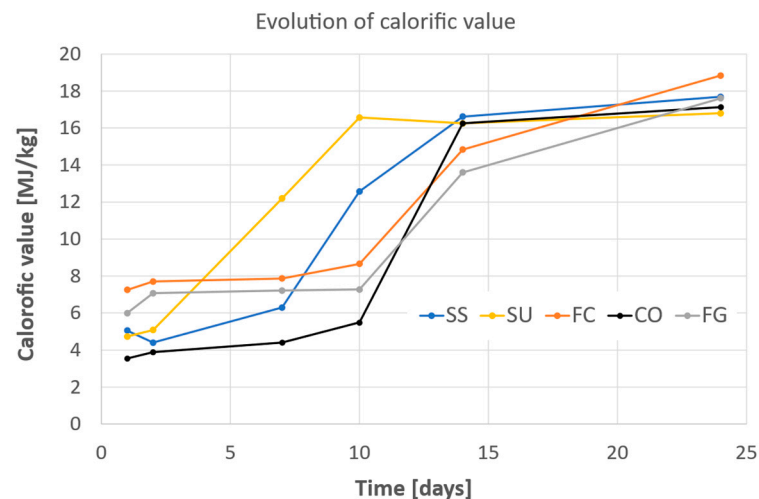


Figure 6. Evolution of the calorific value for the five plant species in the same regular time intervals after irrigation was stopped at time 0 (calorific value as a function of plant moisture).

4.3. Cone Calorimetry

Figure 7 shows the samples before and after the cone calorimeter measurement of the three plant species in the first test where plant moisture is highest (corresponds to Day 1 mentioned above). The measured parameters, namely the peak heat release rate (PHRR) and the maximum average rate of heat emission (MARHE) for the three species are summarized in Table 3.

Carex Oshimensis CO Festuca Gautieri FG Sagina Subulata SS

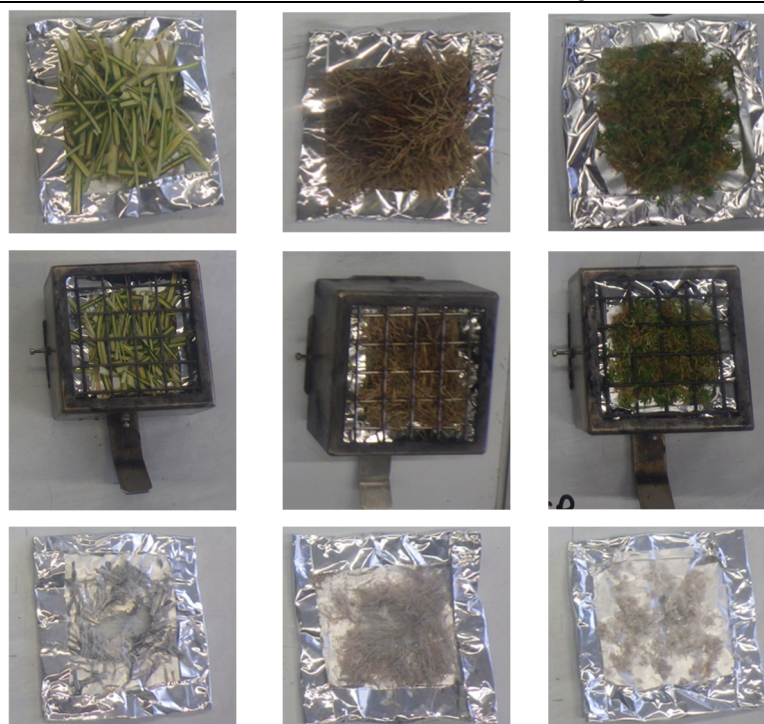


Figure 7. Samples of the three species CO, FG, and SS. In the fresh state (Day 1) for the first measurement (**top**), in the sample holder (**centre**), and after the test with 50 kW/m² (**bottom**).

Table 3. Results of cone calorimetry on the three plant species CO, FG, and SS at three different time intervals after irrigation was stopped (Day 1, Day 7, Day 15). PHRR: “Peak Heat Release Rate” and MARHE: “Maximum Average Rate of Heat Emission”.

Date	Day	Mass [g]	TTI: Time to Ignition [s]	Time to Flame Out [s]	PHRR [kW/m ²]	MARHE [kw/m ²]
CO						
22 February 2022	1	5.5	122	138	14.23	8.5
28 February 2022	7	7.1	30	69	34.99	18.9
8 March 2022	15	6.8	25	61	26.66	16.7
FG						
22 February 2022	1	5.1	146	213	18.78	7.5
28 February 2022	7	7.4	30	164	33.94	18.9
8 March 2022	15	8.8	21	248	51.01	35.3
SS						
22 February 2022	1	5.7	104	122	15.08	7.2
28 February 2022	7	7.2	148	171	12.84	6.8
8 March 2022	15	22.7	1200	Did not burn	13.36	8.7

A summary of the determined parameters by means of cone calorimetry on the three species is given in Table 3. All three show a longer time to ignition (TTI) in the fresh state compared to the two drier states.

A better comparison of the cone calorimetry results regarding the total heat release rate (THRR) is visualized in Figure 8 where the influence of moisture content is demonstrated by three consecutive drying steps, i.e., 0, 7, and 15 days after irrigation stop. Regardless of

the moisture condition and plant variety, most of the heat release occurs in the first 300 s after the onset of ignition, except for *Sagina Subulata* (right) in the dry state, where this occurs evenly over 1200 s. In the next section, where the results of single-flame tests are discussed, the different behaviours of these plant species become clearly visible.

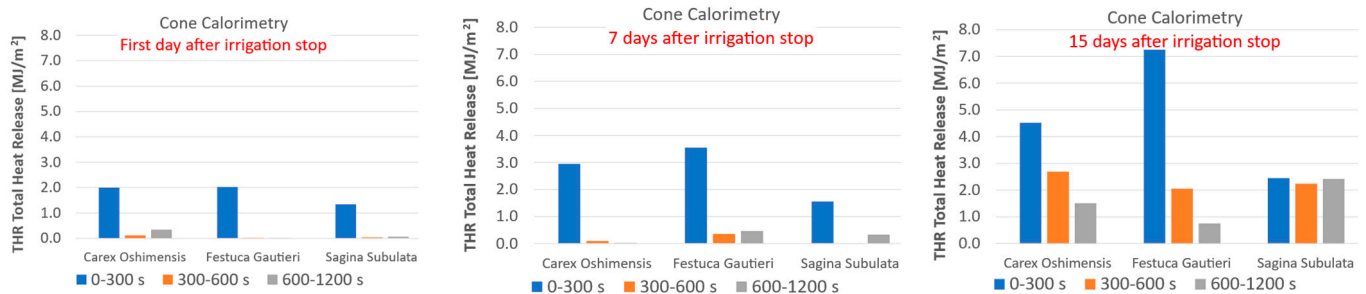


Figure 8. The total heat release (THR) between 0 and 300 s, 300 and 600 s, and 600 and 1200 s after ignition for the three different plant species for 1 day (left), 7 days (middle), and 15 days (right) after irrigation was stopped.

A parameter which is of interest for fire risk is defined as flash-over propensity (FOP) as discussed by Petrella [27]:

$$\text{FOP} = \text{PHRR} / \text{TTI} \text{ [kW/m}^2\text{/s]}$$

with PHRR = peak heat release rate [kW/m²] and TTI = time to ignition [s].

The flash-over propensity is a stage in the development of a contained fire in which all exposed surfaces reach ignition temperatures more or less simultaneously and fire spreads rapidly throughout the space [11].

Figure 9 shows this parameter for the three different plant species at three different times without irrigation, based on the results of the corresponding cone calorimetric tests. All measured values are mainly in the “Low Risk” and towards the lower end of the “Intermediate Risk” region. The values indicated here show that drying of plants increases the risk of flash-over propensity. This increase depends on the type of the plant. It is straightforward to conclude that vertical greenery with healthy live plants has negligible propensity for flash-over. However, when moisture content drops, it may create an intermediate risk of flash-over, and eventually a high risk of flash-over depending on the plant species.

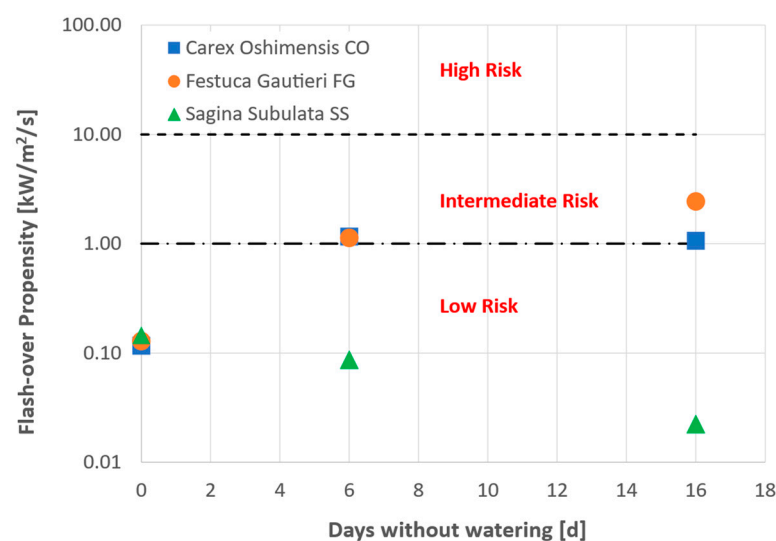


Figure 9. Flash-over propensity calculated according to [27] using results from the cone calorimeter tests for three different plant species.

4.4. Single-Flame Source Test

4.4.1. Carex Oshimensis CO

A slight development of smoke was observed during the test. The direct impact of the flame on the plant caused some leaves to fall off. The material that fell due to the action of the flame formed an ember. The leaves cut off by the fire were not completely burned and could provide a new combustion source. Falling leaves that were not completely burned continued to burn at the bottom of the measuring apparatus for a duration of about 6 s (Figure 10).

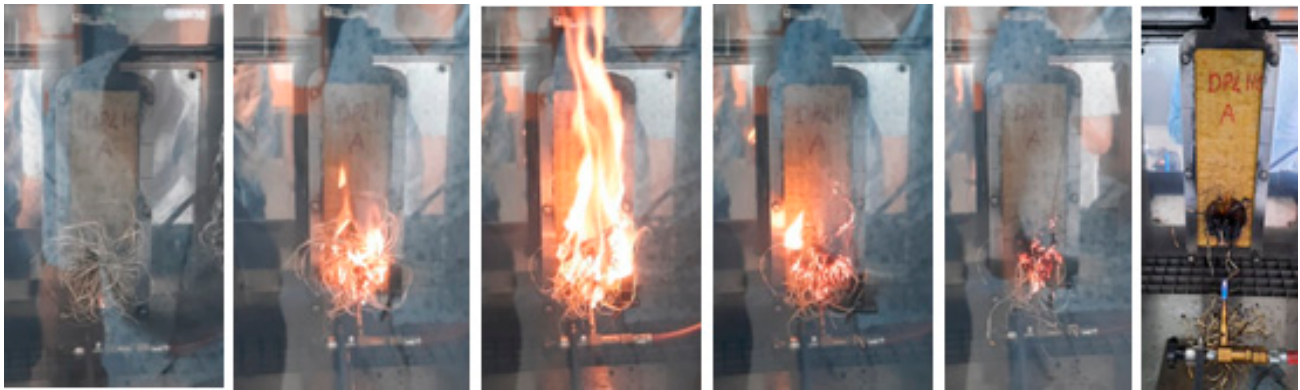


Figure 10. Different stages of ignition of dried Carex Oshimensis CO embedded in mineral wool.

4.4.2. Festuca Gautieri FG

The samples (normal and dried plants) were unstable when exposed to an indirect flame. They ignited when there was a flame nearby. The fire completely and quickly consumed the burning wastes in both humidity conditions. The plants with reduced humidity burned almost completely and developed flames more than 150 mm high, lasting at least 4 s, and were accompanied by heavy smoke development (Figure 11).

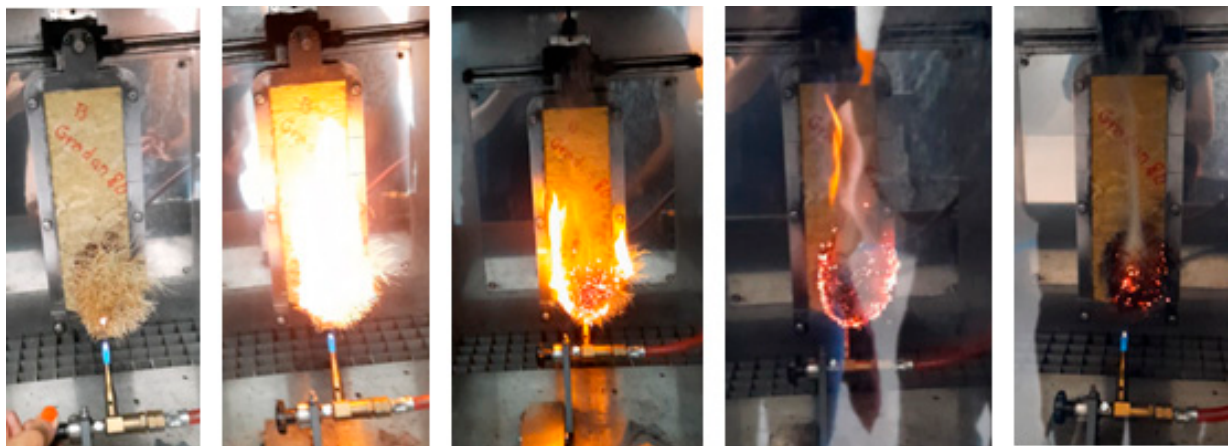


Figure 11. Different stages of ignition of dried Festuca Gautieri FG embedded in mineral wool.

4.4.3. Sagina Subulata SS

The samples (normal and dried plants) did not form a flame front under the influence of a direct flame and produced few embers as the flame only reached the mineral wool directly (Figure 12, first two pictures from the left). When the flame was approaching touching the plant, the formation of embers increased and a rapid but short-term (a few seconds) flame front developed (Figure 12, fourth picture from the left). Increased smoke development occurred. It has also been observed that the flame did not spread within

the dry plant and remained localized even when exposed to a permanent external flame (Figure 12, two pictures on the right end).



Figure 12. Different stages of ignition of dried *Sagina Subulata* SS embedded in mineral wool. Only the direct flame contact with the plant creates a flame front. After the flame is gone, the plant will not continue to burn. The embers gradually peter out.

5. Discussion

This preliminary study shows the flammability and the fire behaviour of different plant species as a function of their moisture content representing a first step towards the understanding of the fire behaviour of a whole living wall system. The plant species tested are appropriate for use in the climatic conditions of Central Europe. The testing methods and equipment are those used for “conventional” materials but in the absence of plant-specific tests methods, these were applied as kind of “auxiliary” procedures. Once established as accepted methods, the topic of repeatability which has not been tackled at this scientific step will become more important and accredited institutes for these tests will have to deal with it.

The bomb calorimetry showed that the individual calorific values of the investigated species all reached approximately the same final amount of 17 MJ/kg 25 days after irrigation stop. This is not much different from the calorific value for different kinds of wood (fir, oak, pine larch) of 19–20 MJ/kg. The different ways in which each species reached this final amount depended on the way it lost its moisture after irrigation stop and provided a first idea of which one can be considered more appropriate for building façades regarding fire risk.

Generally, the majority of the heat is released within the first 300 s of ignition where the plant is nearly fully combusted. The flash-over propensity risk of plants is low to intermediate even in the dry condition. Some of the plants show a higher level of moisture retention capability, making them better candidates for use in living walls concerning fire propagation and maintenance.

Furthermore, these results suggest that the plants should be positioned in such a way that easy-burning plants are interspaced with areas that do not continue to burn when the flame is gone to inhibit flame front progression. The results of the present study are understood as a basis for the next step dealing with whole façade elements mounted on walls and further for a whole real-size façade with vertical greenery. This will be tackled in our future investigations, including single-burning item tests (SBIs) on elements and full-scale tests on complete living walls subjected to a real fire.

Another possible benefit of the presented evaluation methods is to enable the generation of standardised procedures for the evaluation of the fire reaction of plants to be used in living walls.

6. Conclusions

The present study shows the importance of investigating different plant species intended for living walls using existing test procedures and apparatus adapted to the circumstances of the non-geometric shape of the plant samples. The chosen species were appropriate for the climatic conditions of Central Europe but showed nonetheless different behaviour concerning moisture loss after irrigation stop and hence different times to ignition and heat release rates. There was also a different reaction to direct flame contact observed for the different species at different moisture contents. These findings are preliminary to investigate whole façade elements made of one single or multiple plant species in future. All plant species showed a low to intermediate risk of flash-over propensity even in their dry state after 16 days of irrigation stop. Given that the studied materials originated from nature, their ununiformed characteristics could cause deviations in the test results which need to be tackled in a future statistical investigation.

Author Contributions: D.F. carried out the bomb calorimeter tests and commented on the manuscript, K.G.W. wrote the application for the grant, the manuscript, and organized the cone calorimetric measurements, R.d.S. carried out the single-flame source tests, C.R. managed the project, discussed, and commented on the manuscript. All authors have read and agreed to the published version of the manuscript.

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