Proceedings for the 6th International Fire Behavior and Fuels Conference
April 29 – May 3, 2019, Albuquerque, New Mexico USA
Published by the International Association of Wildland Fire, Missoula, Montana, USA

Variation of Pinus halepensis' flammability and fire related traits according to different fire regimes in the northern Mediterranean region

Bastien Romero*
Irstea. 3275 Route de Cezanne, 13100 Aix-en-Provence, France, bastien.romero@irstea.fr

Jean-Michel Lopez
Irstea. 3275 Route de Cezanne, 13100 Aix-en-Provence, France, jean-michel.lopez@irstea.fr

Mathieu Audouard
Irstea. 3275 Route de Cezanne, 13100 Aix-en-Provence, France, mathieu.audouard@irstea.fr

Christian Travaglini
Irstea. 3275 Route de Cezanne, 13100 Aix-en-Provence, France, christian.travaglini@irstea.fr

Anne Ganteaume
Irstea. 3275 Route de Cezanne, 13100 Aix-en-Provence, France, anne.ganteaume@irstea.fr

Abstract

Species having traits adapted to a given fire regime can be endangered when the fire regime changes if these traits do not vary at the same time, especially with the increase in fire recurrence following the global change. In this framework, an on-going PhD work studies plant fire-traits and flammability according to the fire regime to highlight a possible adaptation of these traits which would confer a better flammability to the resilient species *Pinus halepensis* if the fire recurrence increases. The study area is located in the North of Provence (SE France) where the fires will become more intense and more frequent in addition to a change in the biogeographical areas linked to the global change.

Introduction

Wildfires have been shaping landscapes in the Mediterranean regions for thousands years (Keeley et al. 2011), as climate conditions in these areas promote fire ignition and propagation, and most species have adapted because of this high selection pressure. For decades, the increase in temperature has led to an increase in fire activity all over the world. At the global scale as at regional scale (i.e. Mediterranean basin), this trend is likely to be strengthened leading to an increase in risks such as the forest fire risk. Moreover, changes in the boundaries of bio-climatic areas are expected, especially in the northern part of the French Mediterranean region and at higher elevation that should also lead to an increase in the fire risk towards the North. Some species could be impacted by this change, as, for instance, the European mountain trees that are unequally exposed to an increasing fire risk according to their niche flammability, or species present in several bio-climatic areas that are adapted to specific conditions, such as fire regimes (Pausas 2015).

Plant flammability is an important driver that plays a fundamental role in terrestrial ecosystems. Fire-related traits enhancing flammability differ between species and affect different components of

Bastien Romero*
Irstea. 3275 Route de Cezanne, 13100
Aix-en-Provence, France,
bastien.romero@irstea.fr

flammability (Schwilk & Caprio 2011); some plant communities are thus more likely to burn than others. Different adaptation strategies are used by species depending on the fire regime, inducing different fire-related traits. For low to medium intensity surface fires, these traits enable species to survive in case of fire (resistant species) in decreasing the fire impact (thick bark, self-pruning, and large height) and being less flammable (i.e. higher leaf or litter bulk density). On the contrary, resilient species have adapted to high intensity crown fires favouring their post fire regeneration capacity (developing functional traits such as serotiny) and thus enhancing their capability to burn (with structural and chemical traits such as high dead fuel retention, i.e. no self-pruning, high contents of chemical compounds such as terpenes in leaves and litter, or a low fuel bulk density), allowing these species to create their own ecological niche according to the "Born to Burn" hypothesis (Bond & Midgley 1995).

Previous works on plant flammability in fire-prone ecosystems mostly focused on differences between species, especially between different regeneration strategies, and suggested different genetic mechanisms explaining the evolution of flammability (Saura-Mas et al. 2010). However, the functional traits, such as resprouting or serotiny, are adaptive in fire-prone environments, even if the plants are more adapted to a fire regime than to the fire itself (Keeley et al. 2011), and the traits linked to flammability could vary with a change in the fire regime. However, few works, such as that of Pausas et al. (2012), studied the intraspecific variability and its relation to fire regime, but these works generally focused on one type of fuel to assess flammability and on one geographical area (generally within the biogeographical range of the species studied). As stated by Keeley et al. (2011), species having traits adapted to a given fire regime can be endangered when the fire regime changes if these traits do not vary at the same time, especially with the increase of the fire recurrence following the global change, but also with the implementation, in some places, of recurrent prescribed burnings to control the fuel biomass.

The aims of this work were to study the intraspecific variations of the fire related traits and of the flammability according to different fire regimes in order to predict ecosystem responses to on-going global change. We focused on a very well fire-adapted species, *Pinus halepensis*, a resilient species adapted to high fire regime. *P. halepensis* is a typically fire-resilient species adapted to high intensity crown fire regime and is dominant in the region, especially in its southern part and at low elevation. Post-fire *P. halepensis* strategies are based on sexual reproduction and seed development and are related to seed storage in long-closed cones that stay closed pending the arrival of a fire; the high temperature causing the opening of the cones and the seed release (Tapias et al. 2004). This post-fire regeneration totally depends upon this species' canopy-stored seed bank (Ne'eman et al. 2004), mechanism called serotiny. Serotiny and early flowering in *Pinus halepensis* reflect its resilient strategy in relation to fire as this character is advantageous to survive frequent crown fires and to attain successful post-fire recruitment (Tapias et al. 2004). With the global change, *P. halepensis* will be more and more present in the North of Provence.

Sampling

The main challenge of this work was to assess the intraspecific variations of the fire-related traits and flammability in pine populations submitted to different fire regimes avoiding, as much as

Bastien Romero*
Irstea. 3275 Route de Cezanne, 13100
Aix-en-Provence, France,
bastien.romero@irstea.fr

possible, differences in environmental conditions. In order to measure the actual variations due to the fire regime, the populations of *P. halepensis* were sampled according to many environmental similarities (i.e. altitude, exposure, aspect, age of the trees, understorey floristic composition, past land use, etc.).

In order to sample the populations according to two different fire regimes, a map of the fire perimeters (fire size > 2 ha) has been performed using the regional fire database of DDT and satellite images before and after each fire. Three populations were sampled in zones where fires have never occurred (NoFi) and three to five others in zones where several fires (one at least in the northern part of the study area which is less impacted by fires) occurred (HiFi) since the last 60 years.

Flammability

We assessed the branch and the litter flammability in laboratory conditions (Fig. 2a et b). Before each burning experiment, we calculated the Fuel Moisture Content (FMC), ng oven-drying 5 g of fresh material at 60°C for 48h in order to obtain the fuel dry weight.

Litter flammability

For each individual we burned three samples of 20 g of pure litter in a circular aluminum tray and we measured temperatures, flame height, the consumed weight, time to ignition, front flame rate of spread and the flaming duration.

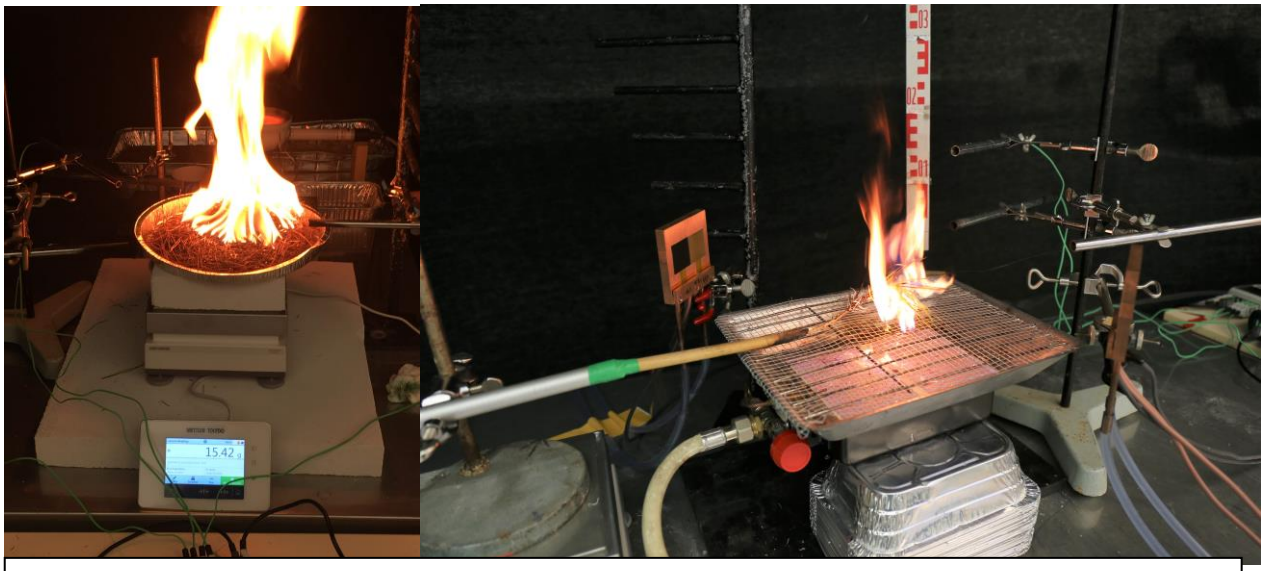

Figure 1: Photo of the burning experiment, for the litter (on the left) and for the branch (on the right)

Bastien Romero*
Irstea. 3275 Route de Cezanne, 13100
Aix-en-Provence, France,
bastien.romero@irstea.fr

Figure 2 shows that there is no clear segregation concerning the litter flammability between the two fire regime modalities. However, the populations subject to higher fire regime (PHF) are more related by higher flame height, higher temperature and higher consumed weight but shorter flaming duration and lower rate of spread. We observed significant differences regarding the flammability variables (one-way ANOVA, n= 180), confirming the trends observed with the PCA.

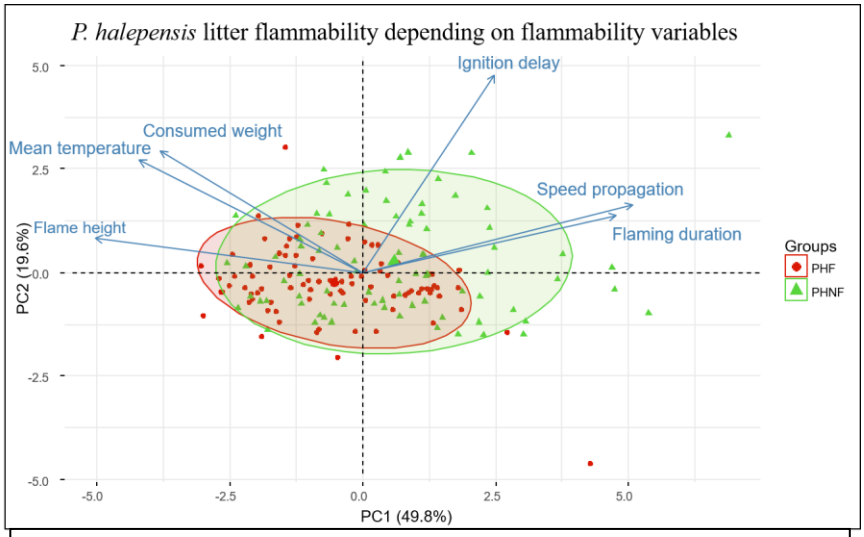

Figure 2: Principal component analysis showing *P.halepensis* distribution depending on flammability variables, for the litter.

Branch flammability

As for the litter burning experiments, we burned three samples for each individual. The branches were selected in order to have a total length of 20cm: 10cm with needles and 10cm without needles. The ignition was made by a radiant heater (4.3kW), we placed the branch 1cm above the grate.

Table 1 resumes the material, the flammability variable measured and the flammability component they belong to:

Table 1: Material, flammability variable measured and flammability components for branch burnings experiments

Material	Variable	Units	Flammability components
3 thermocouples,	Maximal Temperature (Tmax), mean (Tmoy)	°C	Combustibility (Tmax) and (Tmoy)
2 flow meters	Radiative flux, convective and total	W/m²	Combustibility
1 balance	Consumed weight	%	Consumability
1 measuring stick	Maximal flame high	cm	Combustibility
Timer	Ignition delay	s	Ignitability
Timer	Flame duration	s	Durability
Thermometer / Hygrometer	Temperature and relative humidity	°C / %	Co Variables

Bastien Romero*
Irstea. 3275 Route de Cezanne, 13100
Aix-en-Provence, France,
bastien.romero@irstea.fr

Figure 3 shows that there is no clear segregation concerning the branch flammability between the two fire regime modalities. ANOVAs show that individuals belonging to the high fire modality (PHF) have shorter flame height and lowest mean temperature compare to individuals from the other fire modality (PHNF).

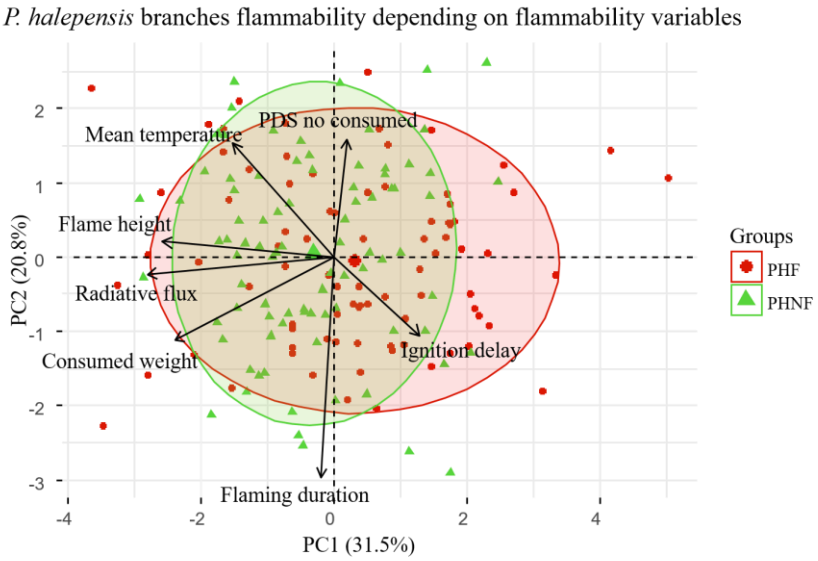

Figure 3: Principal component analysis showing *P.halepensis* distribution depending on flammability variables, for the branches.

Fire related traits

The significant differences were tested for each fire related trait depending on the fire regime modality (Fig. 5). All the fire related traits were significantly different between the two modalities (PHF and PHNF) except the bark thickness. Self-pruning, the surface to volume ratio, the percentage of serotinous cones and the bulk density were higher for the populations belonging to the high fire regime modality (PHF).

Bastien Romero*
Irstea. 3275 Route de Cezanne, 13100
Aix-en-Provence, France,
bastien.romero@irstea.fr

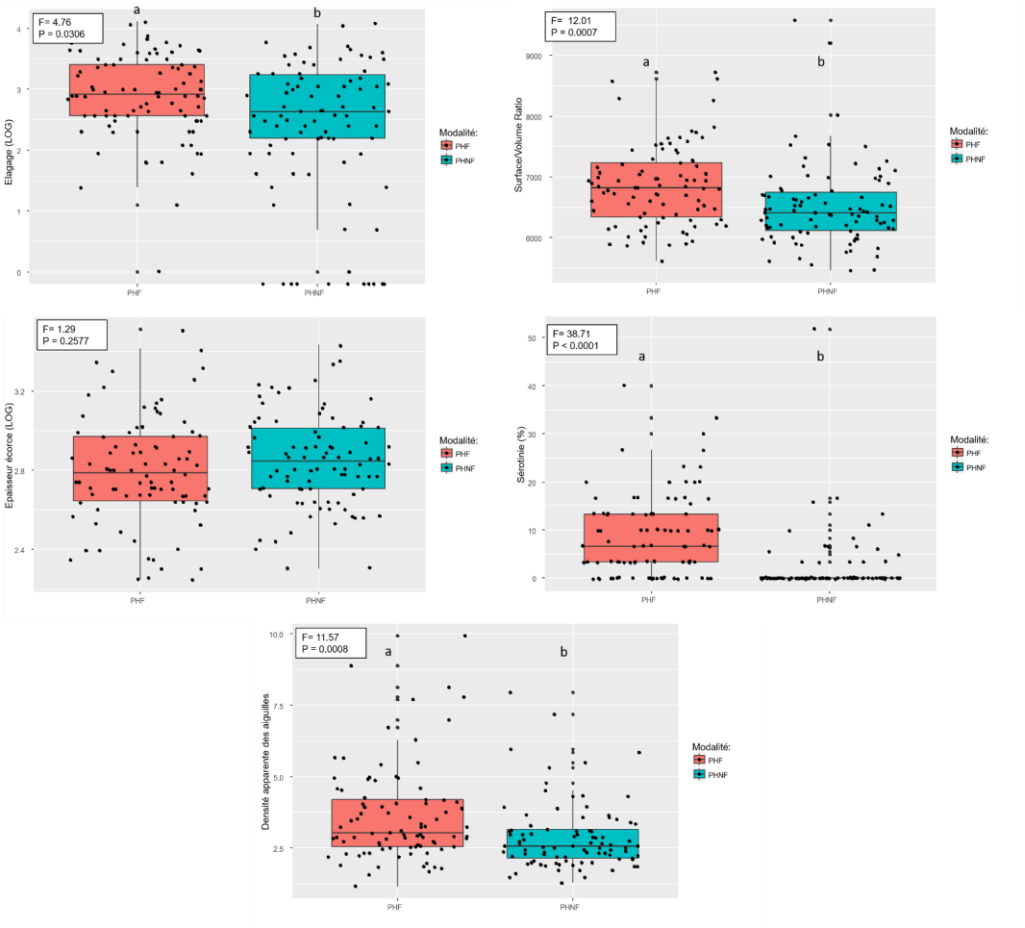

Figure 5: Boxplot showing difference concerning fire related traits for *P. halepensis.* Top left of each graph, ANOVA results (one-way, n= 180). Significant differences are tested with Fischer test (LSD), a>b.

References

Bond, WJ, & Midgley, JJ (1995). Kill thy neighbour: an individualistic argument for the evolution of flammability. *Oikos* 79-85.

Keeley JE, Pausas JG, Rundel PW, Bond WJ, Bradstock RA (2011) Fire as an evolutionary pressure shaping plant traits. *Trends in plant science* **16,** 406-411.

Pausas JG (2015) Bark thickness and fire regime. *Functional Ecology* **29,** 315-327.

Pausas JG, Alessio GA, Moreira B, Corcobado G (2012) Fires enhance flammability in Ulex parviflorus. *New Phytologist* **193,**18-23.

Saura-Mas S, Paula S, Pausas J, Lloret F (2010). Fuel loading and flammability in the Mediterranean Basin woody species with different post-fire regenerative strategies. *International Journal of Wildland Fire* **19,** 783-794

Schwilk DW, Caprio AC (2011) Scaling from leaf traits to fire behaviour: community composition predicts fire severity in a temperate forest. *Journal of Ecology* **99,** 970-980

Tapias R, Climent J, Pardos JA, Gil L (2004) Life histories of Mediterranean pines. *Plant ecology* **171,** 53-68.

Bastien Romero*
Irstea. 3275 Route de Cezanne, 13100
Aix-en-Provence, France,
bastien.romero@irstea.fr