CALIFORNIA FIRE SCIENCE CONSORTIUM

Research Brief for Resource Managers

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Flammable Ecosystems Shaped Three Plant Syndromes

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Plants in fire-prone ecosystems have evolved survival syndromes with respect to flammability (Fig.1). It is proposed in this paper that plants have characteristics that affect flammability in three different ways: ignitability, fire spread rate or speed, and heat release.

Non-flammable plant species have evolved traits that resist ignitions with some combination of characteristics such as thick bark, succulency, simple leaves, or relative height without low branches (Fig.2a,d). In contrast, the other two syndromes have evolved to become very ignitable. To harness and control fire speed, perhaps to train it away from vulnerable organs, *fast-flammable* plants may be extremely oily, retain dried organs in the canopy, or have lots of branches and complex leaves (Fig.2.c). By similarly harnessing fire, *hot-flammable* plants use these same sorts of structures to focus fire and ensure their complete incineration to improve conditions for the next generation. This strategy generates resource gaps for seedling recruitment (Fig.2b).

Scaled up to the community level, these survival syndromes may be consistent, maintained by differing feedback mechanisms (e.g., hot-flammable shrub species in hot-flammable shrublands), but they may also switch, according to the community composition (Fig.2a,d; e.g., non-flammable trees in fast-flammable grasslands). This means that these syndromes aren't necessarily consistent across scales.

Management Implications

- The *non-flammable syndrome* incurs low ignitability and better individual survival odds in fire-prone ecosystems. This strategy works great for conifers and succulents.
- The *fast-flammable syndrome* promotes high flame spread and faster moving fires. Counterintuitively, this keeps localized heating to a minimum, increasing the survival odds of the individual plant. This is a good strategy for resprouters, or for protecting buds.
- The *hot-flammable syndrome* promotes high heat release and ensures the replacement of the individual plant by its own, smoke recruited offspring. This is a good strategy for obligate seeders.
- This **Non-Fast-Hot syndrome scheme** (Fig.1) shows how different plant species may have evolved to resist or use the three dimensions of flammability (ignitability, fire spread rate, and heat release) for higher fitness.

The authors hope that within this non-fast-hot flammable syndrome framework, future research concerning the variability of the three dimensions of flammability across scales should make the study of flammability more tractable.

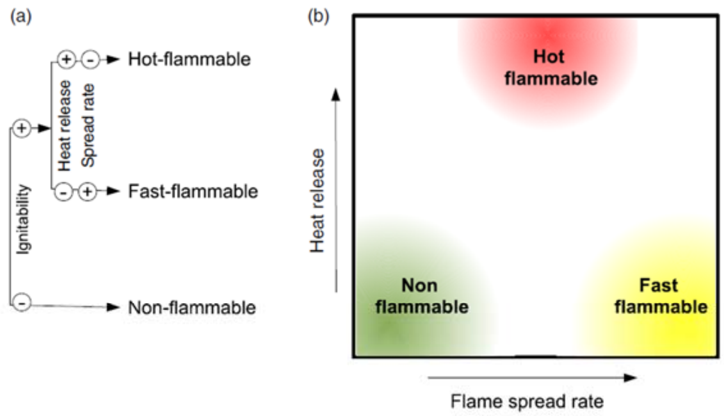

Fig. 1. Conceptual model describing the three plant flammability strategies in fire-prone ecosystems (a and b). The non-flammable strategy refers to plants that do not burn (or rarely) in natural conditions despite living in fire-prone ecosystems: this is because they have biomass with very low ignitability (low flammability at the organ scale, Tables 1 and 2) or because their plant structure does not allow the ignition of the biomass (low flammability at the individual scale). The hot- and the fast-flammable strategies refer to flammable plants with contrasted heat release (kJ g^{-1}; Box 1) and spread rate (m min^{-1}). While many plants fall at intermediate levels of these axes (i.e. the null model for flammability), plants in fire-prone ecosystems benefit from being at the extremes, forming the three flammability strategies considered in this review (Table 1). Note that some species may show different strategies at the different scales which can also be adaptive (e.g. fire-tolerator pines fit in the non-flammable strategy despite having fast-flammable needles; see main text). [Colour figure can be viewed at wileyonlinelibrary.com]

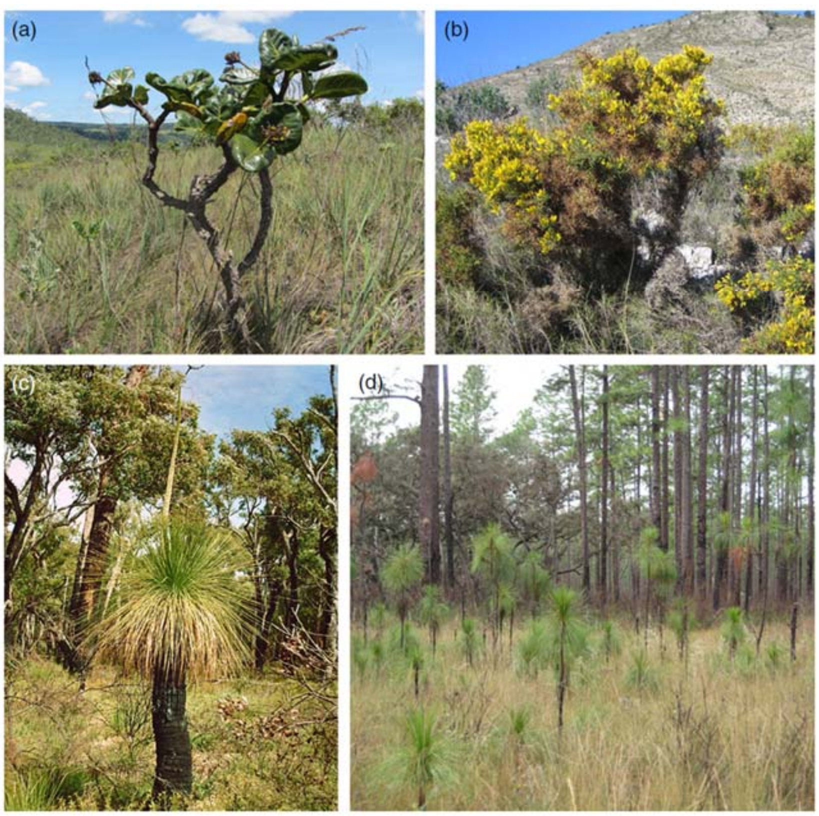

Fig. 2. Examples of species with different flammability strategies. (a) A non-flammable plant (*Palicourea rigida*, Rubiaceae) living in an ecosystem dominated by fast-flammable grasses in a Brazilian savanna (cerrado); note the large and thick leaves and a trunk and branches covered by a thick non-flammable corky bark. (b) A hot-flammable plant (*Ulex parviflorus*, Fabaceae) in a Mediterranean shrubland of eastern Spain; note its fine biomass, the high bulk density and the high amount of standing dead biomass. (c) A recently burnt fast-flammable plant (*Xanthorroea preissi*, Xanthorrhoeaceae) in Australia; note the fine leaves and the post-fire flowering; this species accumulates dead leaves that facilitate burning (not shown in the picture because they were consumed by the recent fire). (d) A forest gap of a frequently burned pine woodland in Florida that shows a fast-flammable (grassy) understorey together with pines (*Pinus palustris*) that have fast-flammable needles but the trees grow quick, and they self-prune the lower branches and thus become non-flammable (photos a, b, d by J.G. Pausas, c by B.B. Lamont). [Colour figure can be viewed at wileyonlinelibrary.com]