Supporting Information

Pausas J.G. & Lamont B.B. Fire-released seed dormancy – A global synthesis.

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Data S1: https://doi.org/10.6084/m9.figshare.19126823.v4

Table S1. Dormancy release syndromes present in fireprone ecosystems, and their ecological properties. Table 2 in the main text is a summary of this table.

	Dormancy release syndromes			
Attribute	**Heat-released physical dormancy**	**Smoke-released physiological dormancy**	**Non-fire-released dormancy**[1]	**Non-dormancy**
Selection drivers	Vegetation gaps whose size and availability vary with fire intensity and patchiness that in turn depend on fire frequency and seasonality and variability of climate	Vegetation gaps whose size and availability vary with fire intensity and patchiness that in turn depend on fire frequency and seasonality and variability of climate	Vegetation gaps whose creation depends on local events such as treefalls and climate effects such as drought death	Suitable germination conditions independent of fire and climate variability, vegetation gaps not critical
Adaptive responses	Long-lived impermeable seeds, fire-cued (heat) dormancy breakage, fire tolerance/avoidance, vegetation gap colonization, full-light tolerant, bet-hedging (variable exposure to heat)	Long-lived permeable seeds, fire-cued (smoke) dormancy breakage, fire tolerance/avoidance, vegetation gap colonization, full-light tolerant, bet-hedging (variable exposure to smoke)	Long-lived seeds, non-fire-cued dormancy breakage, e.g. leaching; fire tolerance/avoidance, gap colonization without change in light conditions, bet-hedging	Short-lived seeds, sometimes recalcitrant, vegetation gap colonization without change in light conditions
Fitness benefits	Survival of fire and adverse germination conditions, matching to optimal (postfire) germination conditions	Survival of fire and adverse germination conditions, matching to optimal (postfire) germination conditions	Can use germination cues for matching to optimal germination conditions unrelated to fire	Quick establishment (drought/granivory avoidance)
Annual response	No germination (dormant)	No germination (dormant)	Germination or remains dormant	Germination or seed mortality
Dormancy type	Physical	Physiological	Variable	No
Dormancy release mechanism	Fire heat causes seed coat tearing or opening of water gap (scarification)	Smoke chemicals (karrikins, cyanohydrins) link with proteins to produce hydrolytic enzymes	Stratification (cold/warm, dry/wet heat) activates hydrolytic enzymes	Not required
Ancillary promoters (additive/rarely synergistic)	Smoke, warm[2]/cold scarification	Ash (nitrogen compounds), charate, fire heat, warm/cold stratification, light	Light (disturbance), maturation, seed-coat decay	Does not apply
Dormancy release	Abrupt	Abrupt	Gradual	Does not apply
Germination requirements	Cool, moist, aerated soil (usually optimal some months after fire), permeable seed coat (created by heat pulse)	Cool, moist, aerated soil (usually optimal some months after fire), enzymes activated by smoke chemicals (seed coat already permeable)	Cool, moist, aerated soil, permeable seed coat (inherent or develops over time)	Moist, aerated soil, cool or warm depending on habitat
Fire response	High germination	High germination	Low germination	Low germination or seed mortality
Peak seedling	Postfire	Postfire	Postfire, any time	Any time (unrelated to fire)

abundance				
Environments where best represented[3]	Mediterranean, warm temperate	Mediterranean, warm temperate	Savannas, non-fireprone cool temperate	Rainforest, succulent desert, saline/rocky habitats
Fire regime	Moderately frequent crown fires	Moderately frequent crown fires	Infrequent or very frequent surface fires	Rarely, if ever, burns
Heat and smoke responses	Heat & smoke promote (H+S+)[4], heat but not smoke promotes (H+S*)	H+S+, smoke but not heat promotes (H*S+)	Neither heat nor smoke promotes (H*S*)	Heat inhibits (H–S*), smoke inhibits (H*S–), both inhibit (H–S–)
Prominent examples	Most Fabaceae, Cistaceae, Malvaceae, Rhamnaceae, Convolvulaceae, Surinacaeae	Many Lamiaceae, Rutaceae, Ericaceae, Poaceae, Proteaceae, Asteraceae, Euphorbiaceae, Anthericaceae, Restionaceae	Some Fabaceae, Poaceae, Asteraceae, Polygalaceae, Asparagaceae, serotinous species[5]	Lecythidaceae, Myrtaceae, Moraceae, obligate resprouters; fleshy-fruited, shade-tolerant species

[1] Includes different dormancy types (physiological, physical, morphological).

[2] Summer temperatures after fire may inhibit germination (Luna, 2020; Lamont *et al*., 2022).

[3] Environments where the type is most prominent; species with non-dormant seeds may occur under any environments and fire regime, including fireprone ecosystems (e.g. obligate resprouters in mediterranean or savanna ecosystems).

[4] H, heat response; S, smoke response; +, positive; –, negative; *, unaffected; also see Fig. S11.

[5] Serotinous seeds remain dormant (secondary dormancy) on the plant until released from their protective structures, usually in response to fire heat (Newton *et al*., 2021); thus, seed release and imposed-dormancy breakage are fire-stimulated but there is no primary dormancy.

Appendix S1. Taxonomic patterns of fire-released dormancy

Production of seeds with fire-released dormancy is widespread among flowering plants. Our collations of fire responses among seven families (1155 species worldwide; data from Data S1 and summarised in Fig. S1) shows that dormancy occurs widely among grasses and graminoids generally: 34% of 157 Poaceae species worldwide possess smoke-released dormancy, as do 85% of South African Restionaceae. Seed dormancy among small shrubs is especially prominent. Among the four categories of fire/non-fire-released dormancy and fire/non-fireprone habitats, 67% of all Cistaceae show heat release (88% of fireprone species), 47% of Lamiaceae are smoke-released and fireprone, and 44% of Australian Rutaceae (including fleshy-fruited) are smoke-released and fireprone (96% of fireprone species have smoke-released dormancy). Large shrubs and trees are common among the 522 Fabaceae species examined, with 52% heat-released and fireprone [this varies greatly from 87% in *Acacia* to 0% in rainforest *Adenanthera*] and 54% of 127 Rhamnaceae species (88% if only the dry-fruited species are considered). Taking an unweighted mean (each family contributing equally to the data) for these seven families (Fig. S1) shows that 60% of all species are in fireprone ecosystems and have fire-released dormancy, and 12% are in non-fireprone ecosystems and are non-dormant. The extent to which these figures can be applied generally is limited as (*a*) there are insufficient data for many families, e.g. Polygalaceae, (*b*) some floras are better studied than others, leading to bias in the data, (*c*) the range of heat or smoke treatments used varied greatly between studies affecting the ability to detect effects (creating false negatives), and (*d*) none of the studies was conducted under field conditions so that their ecological relevance cannot be confirmed. However, despite these limitations, it is clear that there are strong and contrasting associations of seed dormancy with fireprone ecosystems (67.5% of all fireprone species) and non-dormancy with non-fireprone ecosystems (70.6% of non-fireprone species).

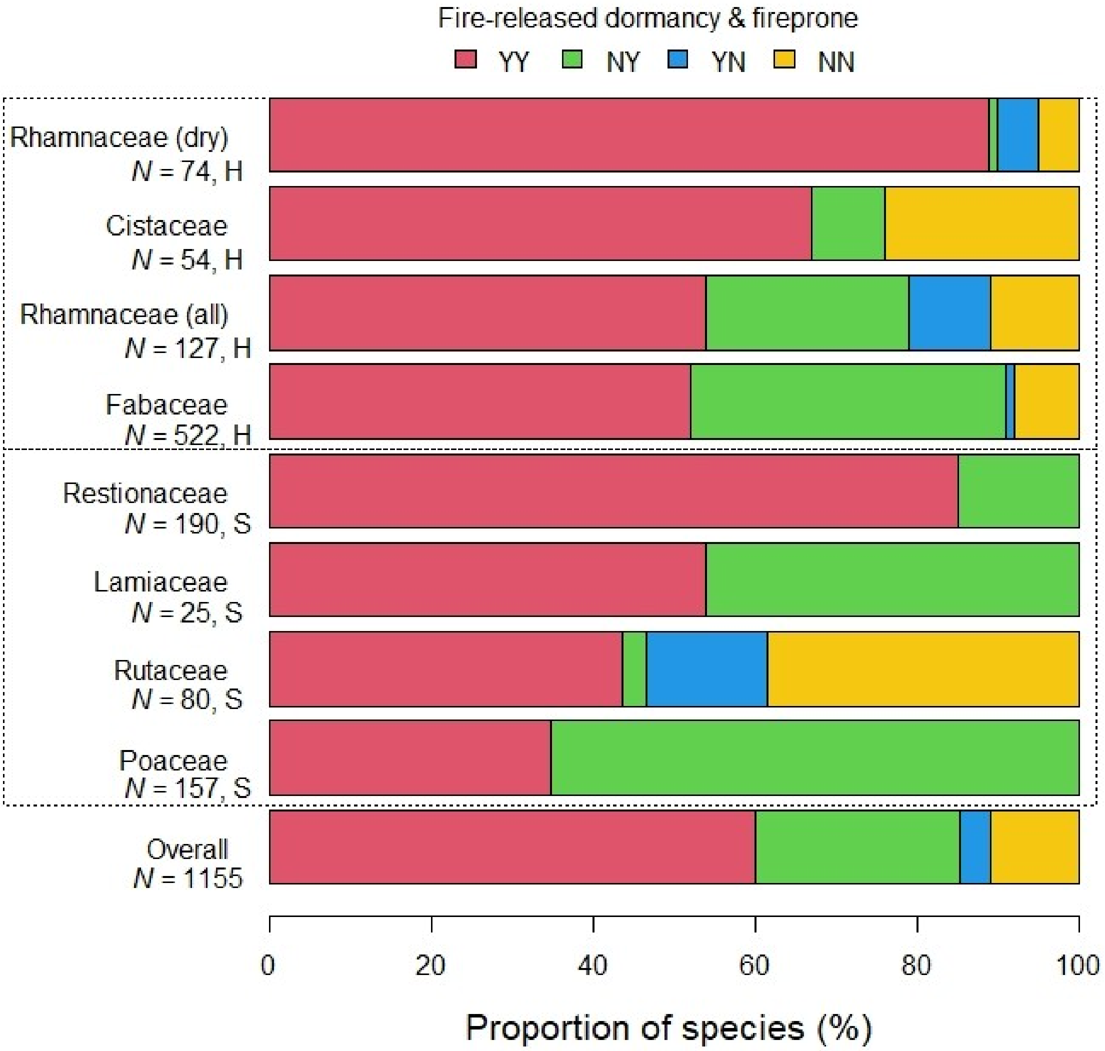

Fig. S1. Summary of our collation of fire responses among seven families with at least some fire-responsive members (totalling 1155 species worldwide). The figure indicates the proportion of species for the combination of fire-released dormancy (Yes/No) and fireprone habitat (Yes/No). Fire-released dormancy includes responses to heat (H) – upper four bars, and smoke (S) – next four bars, and overall – lowest bar. For Rhamnaceae, we included species with dry fruits only (*N* = 74), also dry plus those with fleshy fruits (*N* = 127). The number of species in the family (*N*) refers to those for which data were available. Data from Data S1.

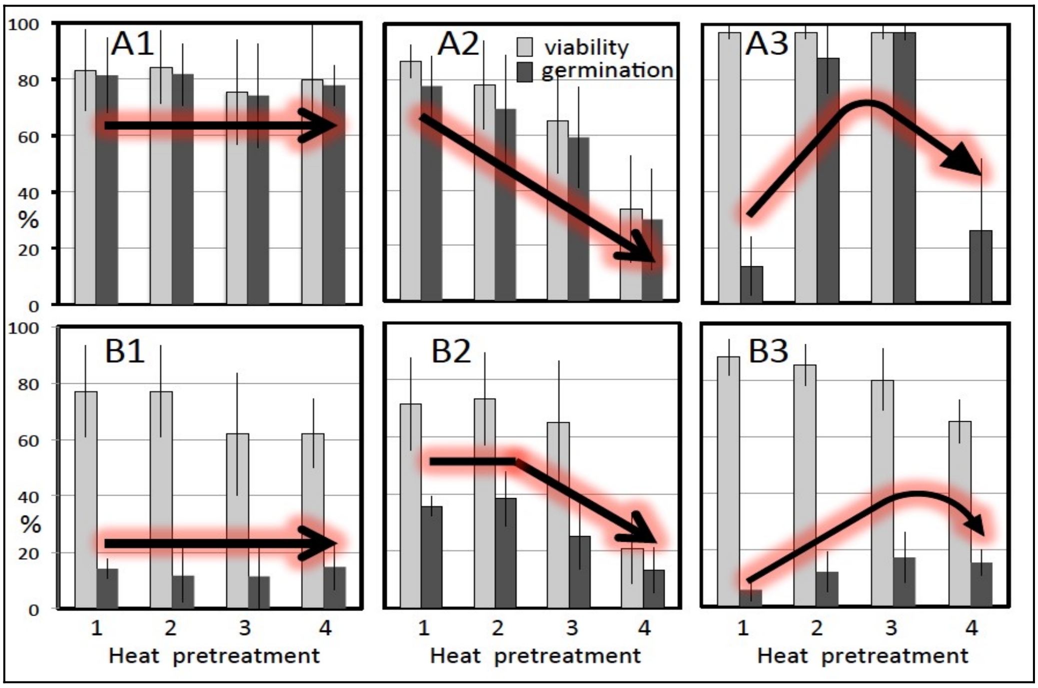

Fig. S2. Illustrations of six categories of dormancy-breaking responses that can be recognized among Fabaceae. Values for categories C1–3 are too low to be shown on this figure but germination trends are as in A 1–3 and B1–3. Data are means ± 95% confidence interval of 5–16 values collated from Auld & O'Connell (1991) and Daibes *et al*. (2019), with the arrows indicating general germination trends. A: both initial viability and germination (under optimal conditions) >50%; B: initial viability > 50% but germination < 50%. Within these categories, 1: viability and germination unaffected by heat pretreatments up to, and including, 200 °C for 1 min (indicating high levels of heat tolerance); 2: viability and germination declining with increasing heat (low heat tolerance); 3: a sharp increase in germination with no change in viability followed by a decline in viability and germination with increasing heat (moderate heat tolerance). For A3 (from Auld & O'Connell, 1991), pretreatment 1 = 40 °C for 1 min, 2 = 60 °C for 1 min, 3 = 100 °C for 1 min, 4 = 120 °C for 1 min. For the other panels (from Daibes *et al*., 2019), 1 = no treatment, 2 = 100 °C for 1 min, 3 = 100 °C for 3 min, 4 = 200 °C for 1 min. Thus, A1 and A2 are essentially non-dormant, A3, B1 and B3 are essentially dormant, and B2 is moderately dormant. A1 and B1 are insensitive to temperature variation, whereas A2, A3 and B2 are highly sensitive, with B3 showing little sensitivity. Only A3 shows the classic bell-shaped germination response curve to increasing intensity of a critical variable.

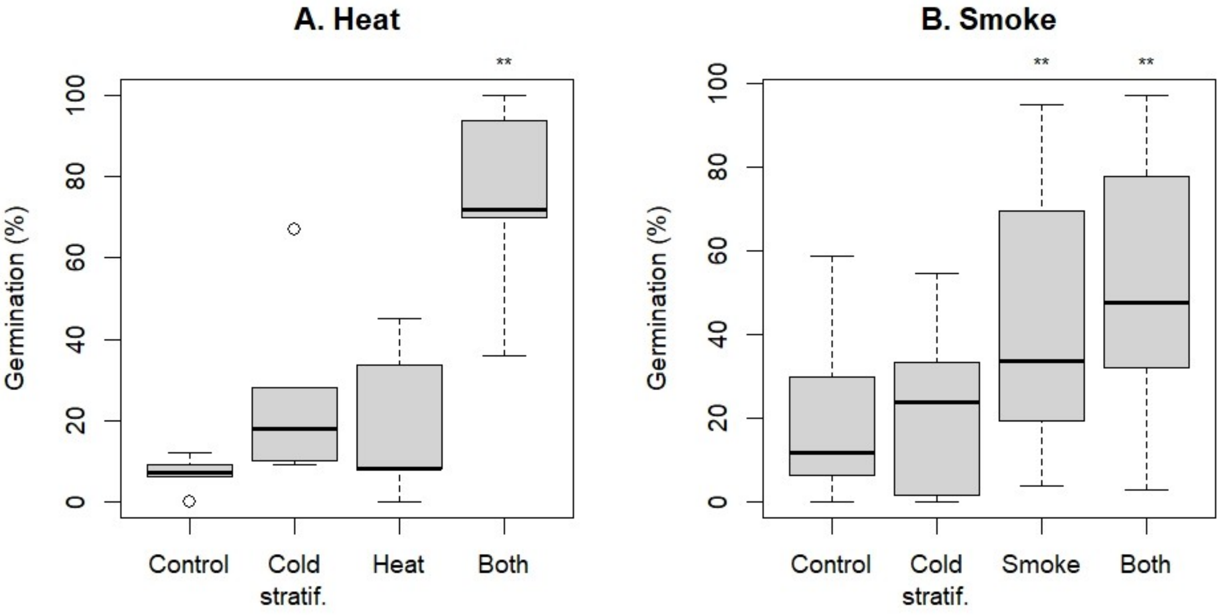

Fig. S3. Summary of interaction between cold stratification and fire-related treatments for (A) five species (*Ceanothus americanus*, *Ceanothus jepsonii*, *Discaria pubescens*, *Lupinus sulphureus*, *Silphium terebinthenaceum*) in individual studies treated with heat (Schramm & Johnson, 1981; Coates, 1996; Kaye & Kuykendall, 2001; McCLain, 2016; Stuurwold, 1972); and (B) 13 populations of *Eschscholzia californica* (Montalvo *et al.*, 2002) treated with smoke. Detailed data for each population and species are given in Fig. S4. Boxplots represent the median (horizontal thick line), the first and third quartiles (box), and the 1.5 interquartile range (whiskers). Asterisks indicate significant differences from the control treatment (**, p<0.01).

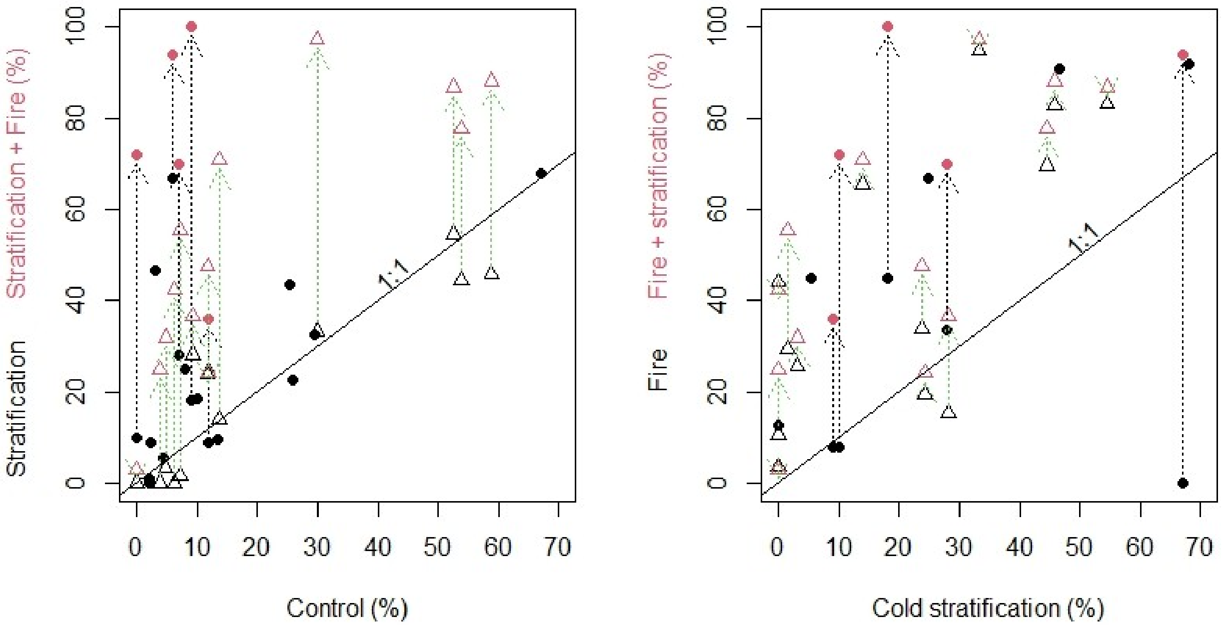

Fig. S4. Interaction between cold stratification and fire-related cues in the germination of ten species with hard seeds in fireprone ecosystems (filled circles), and 13 populations of *Eschscholzia californica* (open triangles). Black symbols (circles and triangles) refer to germination after applying one treatment (cold stratification or heat); red symbols (circles and triangles) refer to the identical species (connected by a dotted arrow) when both treatments are applied together (only available for five species and for the *Eschscholzia* populations). The fire stimulus was smoke for *Eschscholzia* and heat for the other species. (A) Stratification may enhance germination (compared with the control; black symbols) in some species (above diagonal) but not in others (below diagonal), but germination is greatly enhanced when both stratification and fire are applied (red symbols). (B) The same data but plotted as germination after cold stratification against germination after fire only (black symbols) or after cold stratification and fire together (red symbols). A summary of these data for the five species with both cold stratification and fire treatments is plotted in Fig. S3.

Table S2. Germination results for smoke applied to Poaceae species in various ecosystems. Values are the number of Poaceae species in which germination was stimulated (+), unaffected (0), or inhibited (–) by the smoke treatment. Fire types are grass-fuelled surface fires or wood-fuelled crown fires. Note that for site 13 (the Cape, South Africa) results for Restionaceae are used as no data were available for species in its sister family, Poaceae; all nine species of Restionaceae examined at site 12 were also smoke responsive and have been added to the data there.

		Climate		**Fire**	**Smoke-responsive species**			**+ as % total**	
Site	**Ecosystem, location**	**Temperature**	**Rainfall**	**regime**	**+**	**0**	**–**		**References**
1	Tropical savanna, Northeast Australia	Hot	Summer	Surface	3	8	2	23.1	Scott *et al.* (2010); Williams *et al.* (2005)
2	Savanna, North Africa	Hot	Summer	Surface	1	7	0	12.5	Dayamba *et al.* (2008, 2010)
3	Arid savanna, Northwest Australia	Hot	Summer	Surface	8	12	2	36.4	Erickson (2015)
4	Grassland, South Africa	Warm	Summer	Surface	3.5*	15.5	0	18.4	Ghebrehiwot *et al.* (2009, 2013); Smith *et al.* (1999)
5	Tallgrass prairie, Central USA	Warm	Summer	Surface	2	8	0	20	Chou *et al.* (2012); Jefferson *et al.* (2008); Schwilk & Zavala (2012)
6	Cerrado grasslands, Brazil	Hot	Summer	Surface	0	11	0	0	Gorgone-Barbosa *et al.* (2020); Ramos *et al.* (2019)
7	Eucalypt woodland, Southeast Australia	Warm	Uniform	Crown/ surface	17	24	3	38.6	Read & Bellairs (1999); Clarke *et al.* (2000); Tang *et al.* (2003); Penman *et al.* (2008); Carthey *et al.* (2018)
8	Prairie, West Canada	Cold	Summer	Surface	2	7	0	22.2	Abu *et al.* (2016); Yao *et al.* (2017)
9	Shortgrass prairie, Northwest USA	Cool	Summer	Surface	1	5	0	16.7	Ely (2016)
10	Sagebrush steppe, USA	Cool	Winter	Crown	2	4	3	22.2	Blank & Young (1998)
11	Shrubland, Mediterranean Basin	Warm	Winter	Crown	9	2	0	81.9	Adkins & Peters (2001); Dayamba *et al.* (2010); Enright & Kintrup (2001); Long *et al.* (2011); Pérez-Fernández & Rodríguez-Echeverría (2003); Reyes & Trabaud (2009); Stevens *et al.* (2007)
12	Shrubland/woodland, SW Australia	Warm	Winter	Crown	14	0	0	100	Dixon *et al.* (1995); Roche *et al.* (1997, 1998); Smith *et al.* (1999); He *et al.* (2016) for 9 Restionaceae.
13	Shrublands/graminoid wetlands, Cape, South Africa	Warm	Winter	Crown	161	29		84.7	He *et al.* (2016) for Restionaceae

*0.5 allocated when two studies reported opposing results.

Table S3. Effect of smoke on the germination of Lamiaceae species aggregated into two environments: savanna (tropical and subtropical savannas and shortgrass prairie with surface-fire regimes) and shrublands of the Mediterranean Basin (with crown-fire regimes). Smoke effects are: + = germination significantly increased by smoke treatment; – = germination significantly decreased by smoke treatment; 0 = no effect.

Species	**Environment**	**Smoke effect**	**References**
Hyptis spicigera	savanna	+	Scott *et al.* (2010)
Liatris mucronata	savanna	0	Schwilk & Zavala (2012)
Monarda fistulosa	savanna	–	Jefferson *et al.* (2008)
Monarda citriodora	savanna	0	Schwilk & Zavala (2012)
Phlomis olivieri	savanna	+	Naghipour *et al.* (2016)
Pycnanthemum pilosum	savanna	0	Jefferson *et al.* (2008)
Salvia thyrsiflora	savanna	–	Zuloaga-Aguilar *et al.* (2010, 2011)
Salvia azurea	savanna	0	Chou *et al.* (2012)
Salvia coccinea	savanna	+	Schwilk & Zavala (2012)
Salvia farinacea	savanna	+	Schwilk & Zavala (2012)
Salvia iodanthe	savanna	–	Zuloaga-Aguilar *et al.* (2010, 2011)
Salvia lavanduloides	savanna	0	Zuloaga-Aguilar *et al.* (2010, 2011)
Salvia reflexa	savanna	0	Chou *et al.* (2012)
Lavandual pedunculata	shrublands	0	Chamorro & Moreno (2019)
Lavandula latifolia	shrublands	+	Moreira *et al.* 2010)
Lavandula stoechus	shrublands	+ (1 sp.), 0 (2 spp.)	Crosti *et al.* (2006); Catav *et al.* (2015); Chamorro & Moreno (2019)
Origanum onites	shrublands	+	Çatav *et al.* (2014)
Phlomis bourgaei	shrublands	+	Çatav *et al.* (2014)
Rosmarinus officinalis	shrublands	+	Moreira *et al.* (2010)
Satureja thymbra	shrublands	+	Çatav *et al.* (2014)
Sideritis angustifolia	shrublands	0	Moreira *et al.* (2010)
Stachys cretica ssp. *smyrnaea*	shrublands	+	Çatav *et al.* (2014)
Teucrium capitatum	shrublands	0	Moreira *et al.* (2010)
Teucrium divaricatum ssp. *divaricatum*	shrublands	0	Çatav *et al.* (2014)
Teucrium lamiifolium ssp. *stachyophyllum*	shrublands	+	Çatav *et al.* (2014)
Teucrium ronniger	shrublands	+	Moreira *et al.* (2010)
Thymus mastichina	shrublands	0	Chamorro & Moreno (2019)
Thymus piperella	shrublands	–	Moreira *et al.* (2010)
Thymus vulgaris	shrublands	+	Moreira *et al.* (2010)

Table S4. Summary of germination experiments with smoke in different ecosystem types. The table shows the number of species with germination stimulated (+), unaffected (0), or inhibited (–) by the smoke treatments. Ecosystems ordered as in Fig. 3C of the main text.

		Number of species			**Simulated (+) – inhibited (–) /total**	**+ /total**	
Ecosystem type	**Site**	**+**	**0**	**–**	**(%)**	**(%)**	**References**
1. (Sub)tropical rainforest (high uniform rainfall)	Amazon	1*	50	1	0	14.29	Table S10
	Australia, NSW	0	13	0	0	0	Carthey *et al.* (2018)
	Australia, QLD	0	30	0	0	0	Tang *et al.* (2003)
2. Cool temperate shrubland (moderate uniform rainfall)	N Japan	1	21	12	–32.35	2.94	Tsuyuzaki & Miyoshi (2009)
3. Temperate savanna woodland (summer wet)	SW China 1	8	20	6	5.88	23.53	Roeder *et al.* (2019)
	SW China 2	5	25	4	2.94	14.71	Liang *et al.* (2020)
	Sudan	0	12	0	0	0	Dayamba *et al.* (2008)
	México	2	7	3	–8.3	16.7	Zuloaga-Aguilar *et al.* (2011)
	South China	1	10	2	–7.7	7.7	Zhou *et al.* (2014)
4. Dry, semiarid savanna shrubland (summer wet)	Australia, NW, WA	16	65	1	18.29	19.51	Erickson (2015)
	Great Basin, USA	5	20	1	15.38	19.23	Kildisheva *et al.* (2020)
	Australia, mid-QLD	7	12	2	23.8	33.33	Gamage *et al.* (2014)
5. Warm temperate woodland/forest (moderate uniform rainfall)	SE Australia 1	36	118	10	15.85	21.95	Clarke *et al.* (2000); Thomas *et al.* (2003); Keith (1997); Gilmour *et al.* (2000); Kenny (2000); Morris (2000)
	SE Australia 2	27	96	0	21.95	21.95	Read *et al.* (2000)
	SE Australia wetlands	5	9	0	35.71	35.71	Penman *et al.* 2008)
6. Subtropical savanna grassland (summer wet)	Brazil Cerrado	8	25	1	20.59	23.53	Gorgone-Barbosa *et al.* (2020); Fichino *et al.* (2016); Ramos *et al.* (2016); Zirondi *et al.* (2019*a*,*b*)
	USA prairie	10	19	3	21.88	31.25	Jefferson *et al.* (2008)
	Argentina Chaco	4	6	0	40	40	Arcamone & Jaureguiberry (2018)
	S Africa veld	7	29	0	19.44	19.44	Ghebrehiwot *et al.* (2009, 2013)
7. Mediterranean shrubland (Chile) (summer dry)	Central Chile 1	4	4	8	–25	25	Gómez-González *et al.* (2008, 2017)
	Central Chile 2	3	5	2	10	30	Figueroa *et al.* (2009): Figueroa & Cavieres (2012)
8. Mediterranean shrubland/woodland (summer dry)	Mediterranean Basin	11	17	1	34.48	37.93	Moreira *et al.* (2010)
	SW Australia	21	34	0	38.18	38.18	Roche *et al.* (1997, 1998)
	Australia, VIC	23	18	0	56.10	56.10	Enright *et al.* (1997); Wills & Read (2002)

**Jacaranda copaia* also occurs in savanna woodlands.

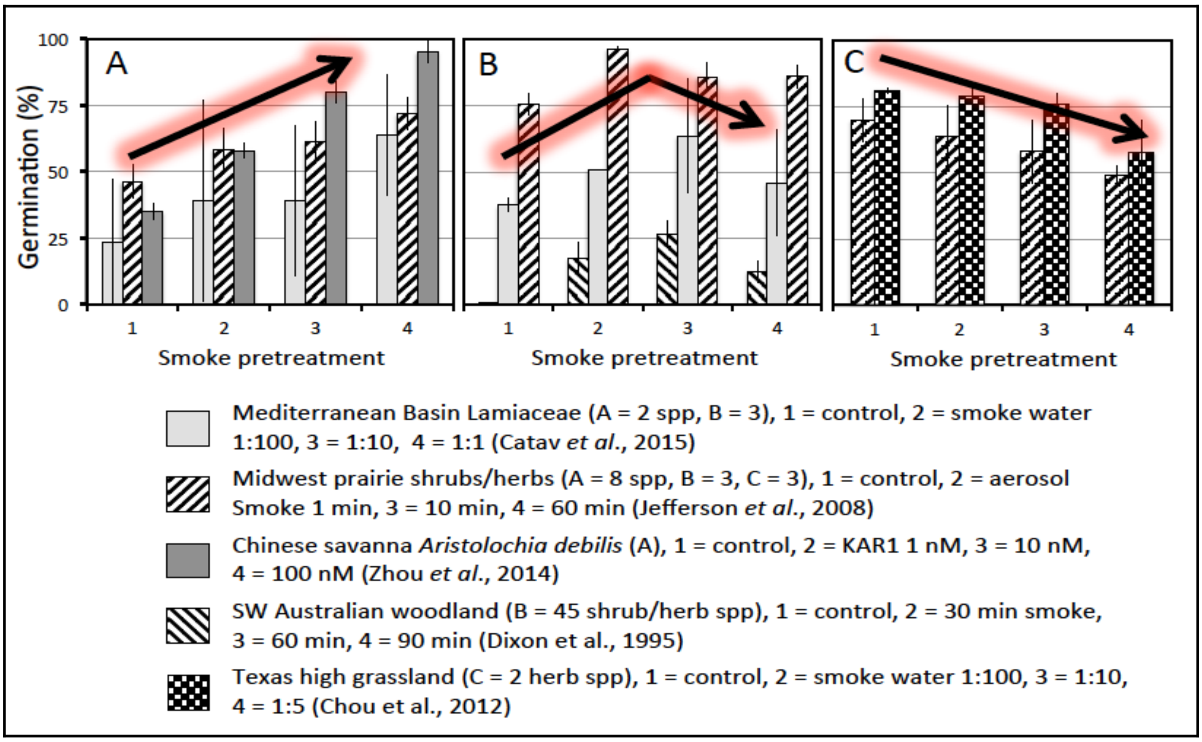

Fig. S5. Illustrations of three categories of smoke-released dormancy/germination responses that can be recognized in various ecosystems worldwide. Direction of the arrows shows the general trends with increasing smoke or karrikin 1 (KAR1) applications, either concentration or duration. (A) Increasing germination with smoke levels; an optimum or inhibitory level of smoke has yet to be reached or does not exist, even though the most intense treatments are unlikely to occur in nature. (B) A bell-shaped curve response to increasing smoke intensity. (C) A mild inhibitory effect of smoke on germination. Other general responses include no effect on breaking dormancy (values close to zero throughout), or lack of dormancy (values close to 100% throughout) that are usually only reported by researchers in a qualitative way. Viability effects (retarding effects as in C) are usually negligible and again are rarely reported. All six categories of smoke response can occur within a given plant community or assemblage of species (Jefferson *et al*., 2008; Reyes & Trabaud, 2009).

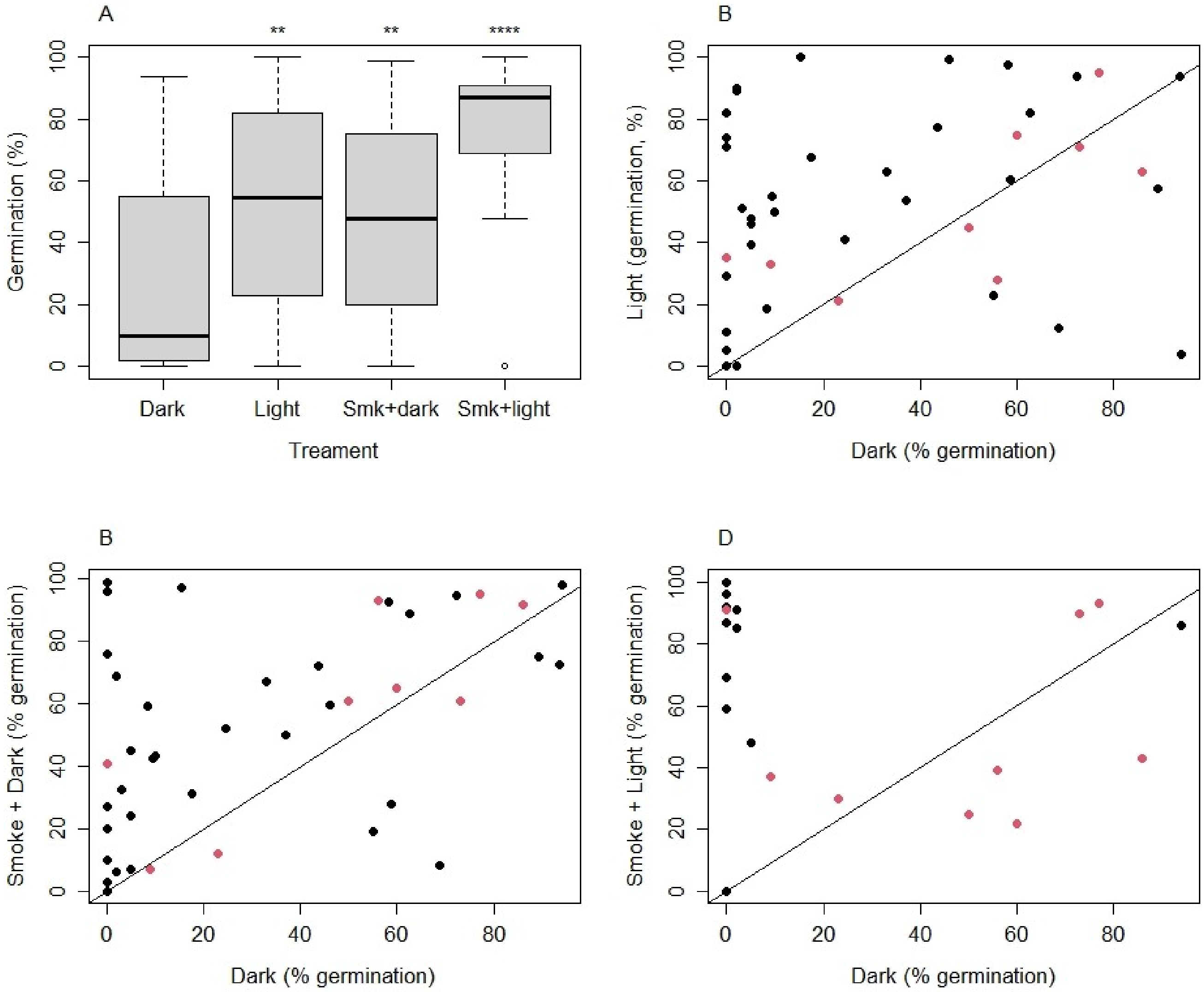

Fig. S6. Interactions between smoke and light on seed germination. Compilation of germination studies with smoke and light treatments (dark *versus* light). Black symbols in B–D are species from crown-fire ecosystems; red symbols are species from savannas (excluded from A); the line indicates the 1:1 relationship [points above the line show increased germination in the *y*-axis treatment compared with the *x*-axis treatment (dark control)]. In A, asterisks indicate a significant effect compared to the Dark treatment (**, $p<0.01$, ****, $p<0.0001$). For species with physiological dormancy, germination is enhanced by light (A, B) by a similar amount as the effect of smoke alone (A, C). However, maximum germination is produced with light and smoke combined (A, D; although fewer studies are available), suggesting that they operate through separate biochemical processes. Thus smoke may enhance germination under suboptimal conditions (dark) as well as under optimal conditions (light). Data taken from Afolayan *et al*. (1997), Brown & van Staden (1997), Clarke *et al*. (2000), Collette & Ooi (2017), Keeley & Fotheringham (1998), López-Mársico *et al*. (2019), Merritt *et al*. (2007), Ramos *et al*. (2019) and Zhou *et al*. (2014).

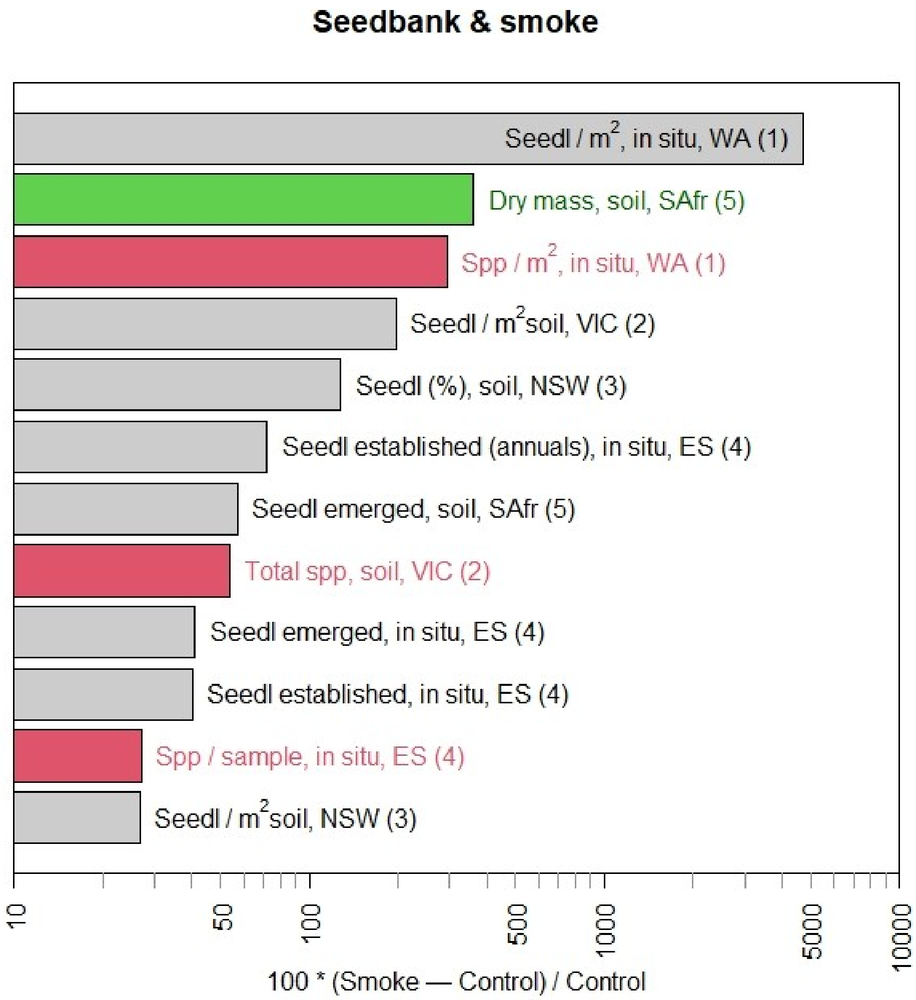

Fig. S7. Effect of smoke on soil seed banks in different crown-fire ecosystems. Changes in the number of seedlings (Seedl, grey bars), species richness (Spp, red bars), and total biomass (green bar) after smoke treatment of soil seed banks, in relation to the control (log scale). Values may have different units, use different methods (in situ = *in situ* smoke application; soil = application to soil samples), and are from different locations in WA: Western Australia (biome 8 in Table S4); VIC: Victoria (biome 5); NSW: New South Wales (biome 5), SAfr: South Africa (biome 8), and ES: Spain (biome 8). All subject to crown fires. Sources: 1, Roche *et al*. (1997); 2, Enright & Kintrup (2001); 3, Read & Bellairs (1999); 4, Tormo *et al*. (2014); 5, Ghebrehiwot *et al*. (2012).

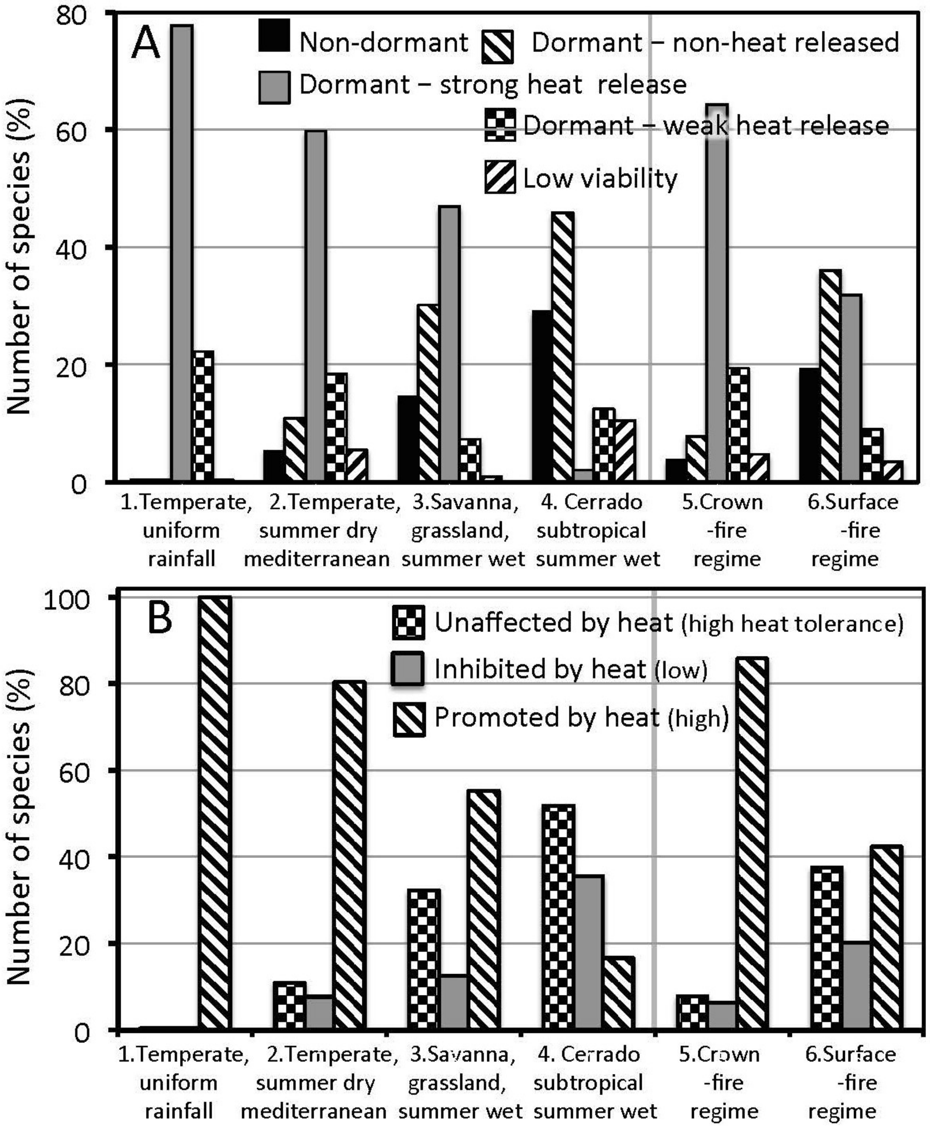

Fig. S8. Summary of data in Table S5 for Fabaceae on a % species per environment and fire-regime basis. Numbers 1–4 correspond to the biomes in Table S5; 5 summarizes data for crown-fire systems (1, 2) and 6 for surface-fire systems (3, 4). (A) Non-dormant (categories A1 + A2; see also Fig. S2), dormant – non-heat released (B1 + B2), dormant – strong heat release (A3), dormant – weak heat release (B3), low inherent viability and (thus) low germination (C1, C2, C3). (B) Germination unaffected by heat and high heat tolerance (A1, B1, C1), germination inhibited by heat and low heat tolerance (A2, B2, C2), germination promoted by heat and high heat tolerance (A3, B3, C3). Entries for the temperate systems (categories 1 and 2) are combined as crown fires (category 5), and the summer-wet systems (categories 3 and 4) are combined as surface fires (category 6). Note the anomalous patterns for the Cerrado and that the combined five sets of values for the other savanna vegetation types are similar to the overall world pattern under 5. While 86% of Fabaceae species show exceptionally high heat tolerances (sum of 5 and 6 in B = 235/272 from Table S5), only 63% have their dormancy essentially released by fire-type heat (171/272). Note that heat tolerance (sum of first and third columns in B) in surface-fire systems is almost as high as that in crown-fire systems but they are only half as likely have their dormancy broken by heat (grey-shaded columns in A).

Table S5. Viability and germination characteristics of the Fabaceae in four major biome types throughout the world, and their surface (*) or crown ($^{\#}$) fire regimes, based on the six categories in Fig. S2 plus an additional three minor categories (C1,2,3) with low viability and germination. The values in the table body are numbers of species for each region listed in the column heading that fall into the nine categories. Note that the Cerrado in Brazil is separated from the rest as its Fabaceae properties appeared unique on a preliminary inspection. See Fig. S8 for a graphical representation of these data.

	Biome:	**4. Cerrado**	**3. Savanna**	**2. Mediterranean (excluding Chile)**	**1.Temperate, uniform rainfall**	**Overall**
	Regions, vegetation type, fire regime	Cerrado, S Brazil, grassy savanna to forest; surface fires*	Savannas/grasslands outside Cerrado: 1, SE USA; 2, Tropical Africa; 3, Mexico; 4, NW/N/NE Australia; 5, Chaco, Patagonia; surface fires*	Mediterranean regions, shrublands, woodlands, forest: SW Australia, Mediterranean Basin, Cape of S Africa; crown fires$^{\#}$	SE Australia, Eucalypt forest/ woodland warm temperate uniform rainfall; crown fires$^{\#}$	Total (adding Chile and Transylvania)
	Fabaceae species	48	96	92	36	272 + 6 = 278
Category - Viability (V %), Germination (G %)	**Subcategory – response curve**					
A. V > 50, G > 50	1. G unaffected by heat	5	0 + 2 + 0 + 1 + 3 = 6	0 + 1 + 0 = 1	0	12 + 0 = 12
	2. G unaffected then sharp decline, or declines from outset	9	3 + 3 + 0 + 1 + 1 = 8	0 + 4 + 0 = 4	0	21 + 0 = 21
	3. Optimum (bell-shaped) temperature respones for G, rarely still rising at highest heat treatment	1	7 + 10 + 11 + 8 + 9 = 45	13 + 40 + 2 = 55	28	129 + 2 = 131
B. V > 50, G < 50	1. G unaffected by heat	16	5 + 5 + 1 + 10 + 4 = 25	4 + 2 + 1 = 7	0	48 + 3 = 51
	2. G unaffected, then sharp decline	6	1 + 3 + 0 + 0 + 0 = 4	3 + 0 + 0 = 3	0	13 + 0 = 13
	3. Optimum temperature for G	6	1 + 4 + 0 + 1+ 1 = 7	11 + 5 + 1 = 17	8	38 + 1 = 39
C. V < 50, G < 50	1. G unaffected by heat	2	0 + 0 + 0 + 0 + 0 = 0	1 + 1 + 0 = 2	0	4 + 0 = 4

	2. G unaffected, then sharp decline	2	0 + 0 + 0 + 0 + 0 = 0	0 + 1 + 0 = 1	0	3 + 0 = 3
	3. Optimum temperature for G	1	0 + 1 + 0 + 0 + 0 = 1	0 + 2 + 0 = 2	0	4 + 0 = 4
	References	Daibes *et al.* (2019); Souza *et al.* (2015); Ribeiro *et al.* (2013)	Martin *et al.* (1975); Wiggers *et al.* (2013); Dittus & Muir (2010); Jaureguiberry & Díaz (2015); Galindez *et al.* (2016); Martinat & Fuentes (2016); Gashaw & Michelsen (2002); Mbalo & Witkowski (1997); Agboola *et al.* (2005); Williams *et al.* (2003); Scott *et al.* (2010); Teketay (1996*a*,*b*); Zuloaga-Aguilar *et al.* (2010); Garduza-Acosta *et al.* (2020); Robles-Díaz *et al.* (2016); Bautista-Rodriquez *et al.* (2017); Erickson (2015)	Kazanci & Tavşanoğlu (2019); Herranz *et al.* (1998); Reyes & Trabaud (2009); Luna *et al.* (2007); Moreira *et al.* (2010); Moreira & Pausas (2012); Jeffery *et al.* (1988); Bell *et al.* (1993)	Auld & O'Connell (1991); Morris (2000)	Gómez-González *et al.* (2017); Ruprecht *et al.* (2013)
Dormancy characteristics						
1. Non-dormant (A1 + A2)		14	14	5	0	28* + 5#
2. Dormant – non-heat release (B1 + B2)		22	29	10	0	51* + 10#
3. Dormant – strong heat release (A3)		1	45	55	28	46* + 83#
4. Dormant – weak heat release (B3)		6	7	17	8	13* + 25#
5. Unaffected by heat (A1, B1, C1)	High heat tolerance	23	31	10	0	54* + 10#
6. Inhibited by heat (A2, B2, C2)	Low heat tolerance	17	12	8	0	29* + 8#
7. Promoted by heat (A3, B3, C3)	High heat tolerance	8	53	74	36	61* + 110#

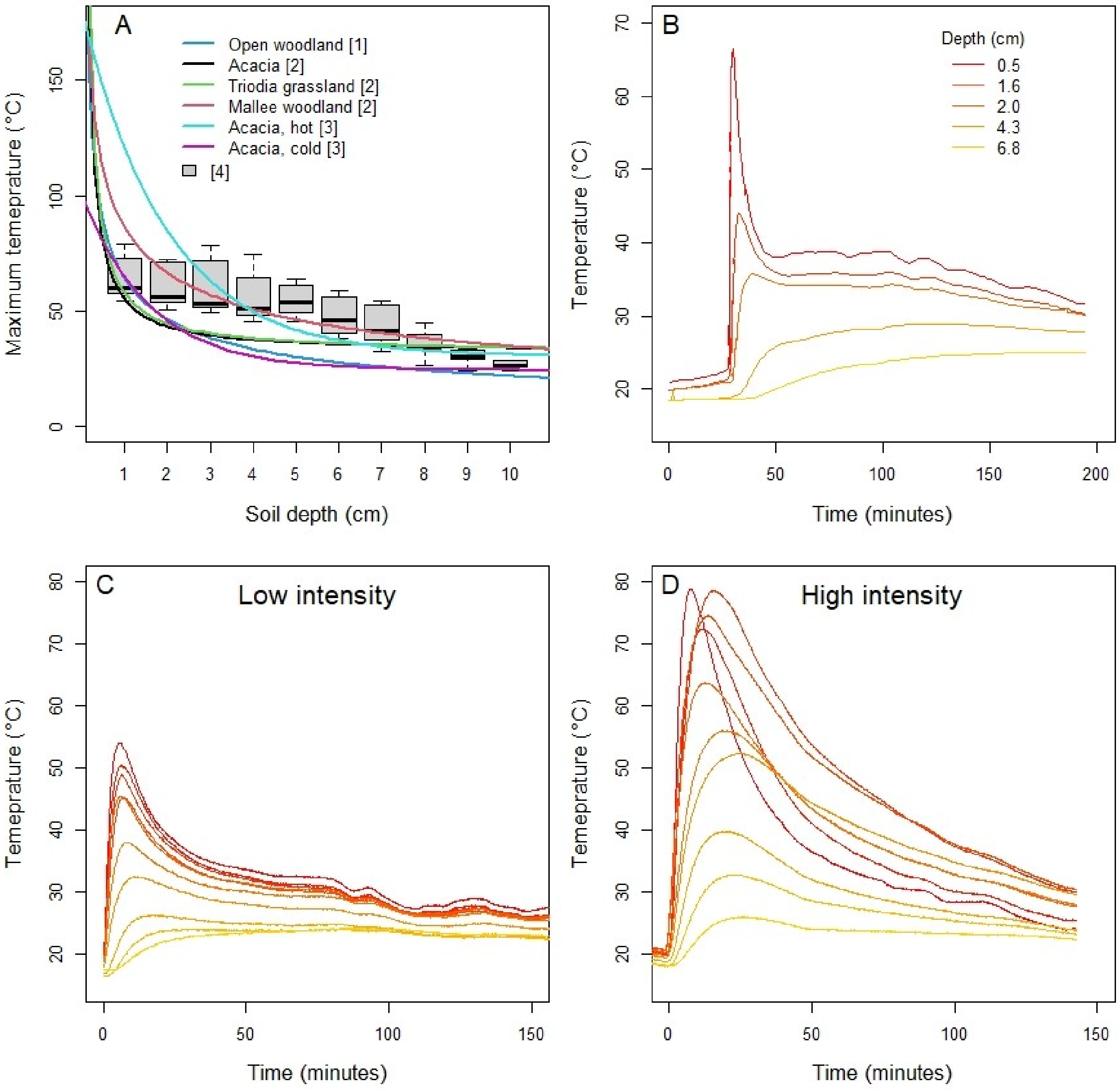

Fig. S9. Soil temperatures during experimental fires. (A) Maximum soil temperatures as a function of depth. Numbers in square brackets are the source: [1], Bradstock *et al*. (1992); [2], Bradstock & Auld (1995); [3], Auld (1986; burns at two intensities); [4], Tangney *et al*. (2020) for a range of fire intensities. (B–D) Examples of the time course of soil temperatures prior to and during an experimental fire, with temperature sensors at different depths (dark red are top layers and yellow lower layers): (B) 0.5–6.8 cm depth (Bradstock & Auld, 1995); (C, D) 0–10 cm depth (Tangney *et al*., 2020).

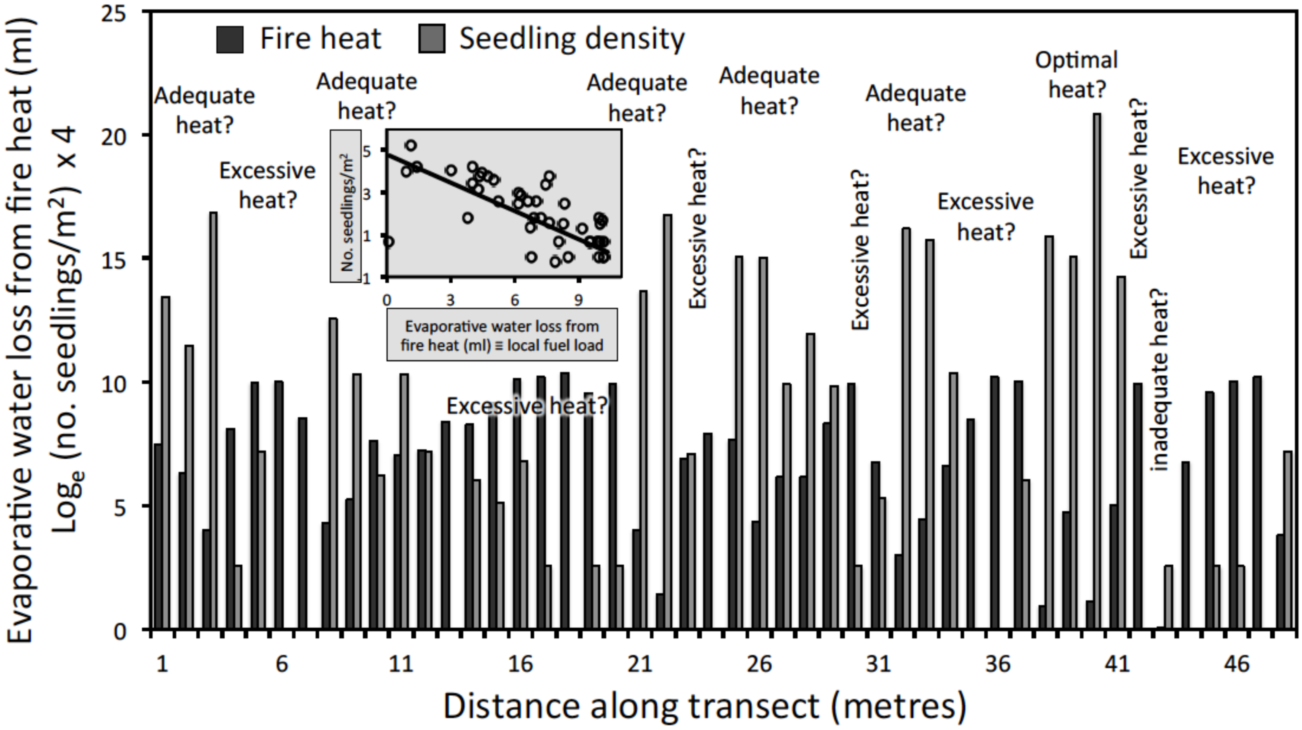

Fig. S10. Transect through a recently burnt sclerophyll shrubland in California. Number of seedlings was counted per m^2 of transect and compared against the burnt-fuel levels there based on evaporative water loss from dishes placed in the centre of the plots. Inset: number of seedlings *versus* evaporative water loss. Results highlight local patch effects on germination of dormant seeds; conditions are sometimes adequate, sometimes inadequate or can be excessive for dormancy release. Collated from Odion & Davis (2000).

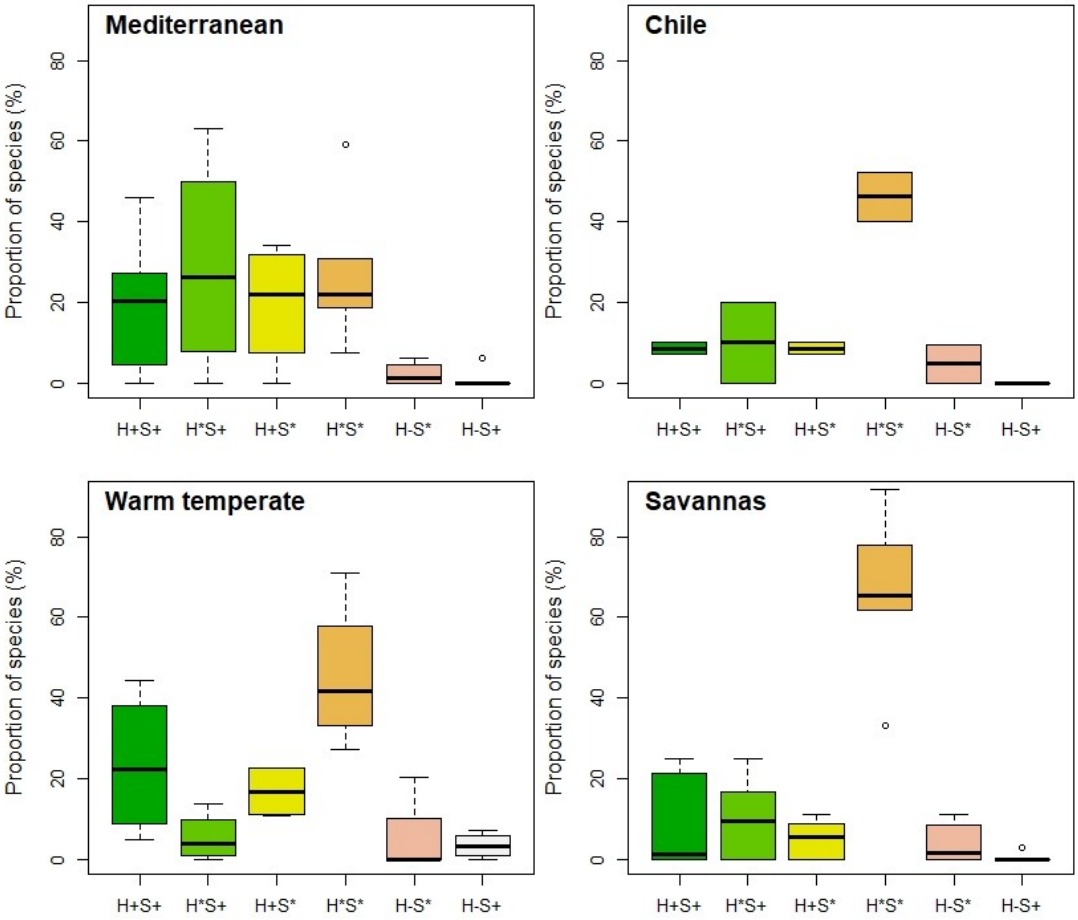

Fig. S11. Percentage of species with release from dormancy stimulated (+), inhibited (–), or unaffected (*) by heat (H) and/or smoke (S) in four environment categories (see Table S6 for definition of the four environments). Chile was separated out from other mediterranean regions as it has a lower fire history than the other mediterranean regions and shows a different pattern. The Cerrado was not distinguished from other savannas here as its pattern was very similar. Semi-arid regions recorded here had summer rainfall and were grouped with the savannas. Almost no species possessed combinations of H and S not shown here (i.e. H–S–, H*S–, H+S–). Note that only studies that tested both heat and smoke in a fully balanced trial on a set of species within a nominated community are reported here. Mediterranean ecosystems (crown-fire regime) show a more even distribution among the three fire-released dormancy types (H+S+, H*S+, H+S*; each accounting for 20–25% of species) than warm temperate ecosystems (also with crown fires). In savannas, species with fire-released dormancy are present but are less abundant; the seeds do tolerate fires, but, for the great majority, their dormancy is not broken by fire (H*S*). In these ecosystems, smoke seems more relevant than heat in terms of representation among species but not in terms of effect where heat has a greater stimulatory effect on germination (see Fig. 5). Overall, germination of 42% of the species was stimulated by heat and/or smoke, 49% were unaffected by both (i.e. were both heat and smoke tolerant), and 9% were inhibited by heat and/or smoke. Based on 586 species in 27 studies (Mediterranean: 6, Chile: 2, Warm temperate: 7, Savanna: 12). Data sourced from Abella *et al*. (2007), Baker *et al*. (2005), Clarke *et al*. (2000), Clarke & French (2005), Cuello *et al*. (2020), Dayamba *et al*. (2008), Enright *et al*. (1997), Enright & Kintrup (2001), Figueroa & Cavieres (2012), Figueroa *et al*. (2009), Ghebrehiwot *et al*. (2012), Gómez-González *et al*. (2017), Jurado *et al*. (2011), Keeley & Baer-Keeley (1999), Keeley & Bond (1997), Montalvo *et al*. (2002), Read *et al*. (2000), Reyes & Trabaud (2009), Rivas *et al*. (2006), Roeder *et al*. (2019), Thomas *et al*. (2003), Tieu *et al*. (2001), Williams *et al*. (2003), Wills & Read (2002) and Zirondi *et al*. (2019*b*).

Table S6. Descriptions of biogeographic regions used in Fig. S11. Chile was separated out here from other mediterranean regions as it has a lower historical fire activity and its properties showed much more affinity with the savannas (see last entry). The Brazilian Cerrado was not distinguished from other savannas as it appeared typical in terms of seed dormancy. Semi-arid regions recorded here had summer rainfall and were also grouped with the savannas.

	Mediterranean	**Chile**	**Warm temperate**	**Savannas**
Regions	Mediterranean Basin; mediterranean Australia, South Africa, California	Central Chile	SE Australia	Central-SE USA, Brazil Cerrado, Patagonia, Middle East, Central-S Africa, SW China, N Australia
Rainfall pattern	Summer drought	Summer drought	Aseasonal	Summer rainfall
Climate (Köppen-Geiger classification[1])	Mediterranean (Csa, Csb, BSk)	Mediterranean (Csb)	Warm temperate (Cfa, Cfb)	Tropical seasonal, steppe to semi-arid (BSh, BSk, BWk, Cwa, Cwb, Cfa)
Vegetation	Shrubland, woodland, forest	Shrubland	Shrubland, woodland, forest	Grassland, savannas, and open woodland
Fire regime[2]	Crown, 20–50 year intervals, moderate–intense	Crown, 50–100 year intervals, moderate	Crown, 20–50 year intervals, moderate-intense	Surface, 2–5 year intervals, low–moderate
Diaspore dispersal agents	Vertebrates, ants, wind	Vertebrates, wind, passive	Vertebrates, ants, wind	Vertebrates, wind, passive
Seed dormancy	Common (~80%)	Moderate (~50%)	Moderate (~50%)	Not common (~30%)

[1] Köppen-Geiger classification from Peel *et al*. (2007).
[2] Fire regime classified according to Rundel *et al*. (2018).

Table S7. Changes in seed traits through evolutionary time in response to changes in climate and fire regime. Pathways A1 and A2 lead to gain of fire-related traits and pathways B1 and B2 lead to loss of fire-related traits. Arillate refers to possession of a caruncle that serves as an elaiosome that is attractive to ant dispersers. Note that many of the fire regime allocations are estimates as environments associated with fossil data are poorly documented; most of the trait allocations are based on ancestral-trait assignments on molecular phylogenies in the absence of accurately dated fossils and are therefore indirect [see Lamont *et al*. (2019*b*) for methods].

Clade	Early location	Early habitat and fire regime	Early seed trait	Later speciation	New habitat and fire regime	New seed trait	Time of origin of new trait (Ma)	References
Pathway A1. Migration from non-fireprone to fireprone habitat (gains fire-related trait)								
Proteaceae	Gondwana – possibly NW Africa	Rainforest, non-fireprone	Non-soil-stored, non-serotinous	Early Proteaceae differentiates into subfamilies, here Proteoideae	Sclerophyll woodlands, drought-prone, fireprone	Fire-related: soil-stored (50% probability) and serotinous (50% probability)	8580 (9590) (stemcrown of Proteoideae)	Sauquet *et al.* (2009); Lamont & He (2012; updated by T. He, personal communication)
Proteaceae, stem of series Proteae	Cape, S Africa	Forest/woodland, non-fireprone	Non-soil-stored, non-serotinous (like *Faurea*, sister to *Protea*)	*Protea* separates from *Faurea*	Fireprone shrublands,	Enforced dormancy (serotinous), fire-stimulated seed release	70–28	Lamont *et al.* (2013)
Proteaceae, *Banksia*	Australia	Rainforest, non-fireprone	Non-serotinous, non-dormant	*Banksia* separates from rainforest *Musgravea* clade	Fireprone sclerophyll woodland/forests, SW Australia?	Serotinous cones, enforced dormancy, fire-stimulated seed release	61–48 (probably an underestimate)	He *et al.* (2011); Lamont & He (2017*b*)
Proteaceae, Persoonieae	Australia, New Zealand	Rainforest, non-fireprone	Non-dormant, drupaceous	Persoonieae in Australia separates from rainforest *Placospermum* clade, and *Toronia* in New Zealand	Fireprone sclerophyll woodland/forests	Semisucculent with stony endocarp (pyrene), vertebrate-dispersed, dormant, dormancy released by fire-	23–14	Auld *et al.* (2007); Lamont & He (2012)

						type heat		
Ecdeiocoleaceae	SW Australia?	(Sub)tropical rainforest, non-fireprone	Drupes vertebrate-dispersed, soil-stored, dormant gradually losing dormancy	Ecdeiocoleaceae separates from *Flagellaria–Joinvillea*	Fireprone shrublands, C_3 grasslands	Achenes, passively dispersed, soil-stored, dormancy released by smoke and postfire fluctuating temperatures	73.5–54	Randriatafika *et al.* (2007); Baskin *et al.* (2004); Lamont *et al.* (2019*b*)
Restionaceae	S Africa and Australia	Woodlands/ shrublands, graminoid wetlands	Possibly non-dormant, but immediate S African ancestor unknown	Restionaceae, S African clade separates from Australian clade	Fireprone shrublands, graminoid (C_3) wetlands	Semihard capsules/nutlets, soil-stored, smoke-released dormancy	70–46[#]	He *et al.* (2016)
Fabaceaae	Africa	Non-fireprone rainforests	Basal Polygalaceae: *Xanthophyllum*, *Moutabea* and *Carpolobia*, soft-seeded, non-soil-stored, no water gap	Fabaceae–Surianaceae clade separates from Polygalaceae	Fireprone forests	Hard–cutinized, sclerified palisade, osteosclereid layer, light line, lens (cracks on heating to create water gap)	109–105 (Fabaceae separates at 93–92, many later acquiring arils in more intensely burnt regions)	Forest *et al.* (2007); Li *et al.* (2015), Pausas & Lamont (2022), Lamont *et al.* (2019*b*; Polygalaceae incorrectly given as hard-seeded, corrected here)
Dipterocarpaceae *sensu lato*	Africa	Rainforest, non-fireprone	Soft testa, lacking dormancy, often recalcitrant (all and only dipterocarpoid Dipterocarpaceae)	*Pakaraimaea*–Cistaceae–(Bixaceae) separate from rainforest Dipterocarpaceae	Fireprone forests	Hard testa, possibly fire-type heat-released dormancy (benefit from scarification)	77–61 (probably underestimated – see *Pakaraimaea* below)	Tompsett & Kemp (1996, in Apannah & Turnbull, 1998); Thanos *et al.* (1992); Nandi (1998); Heckenhauer *et al.* (2017); B. B. Lamont (unpublished)
Poaceae	Worldwide?	Open vegetation, rarely fireprone?	Seed type permeable and non-dormant	Fireprone C_3 grasses separate from non-fireprone C_3 grasses and from fireprone	Fireprone shrubland to open woodlands	Seeds dormant, remain permeable to water but now smoke sensitive for breaking	73.5–55 (no ancestral trait assignments made so most likely dates	Lamont *et al.* (2019*b*)

				Ecdeiocoleaceae		dormancy	unclear)	
Pomaderreae, Rhamnaceae	S America, Antarctica, Australia?	Non-fireprone (non-sclerophyllous) rainforest	Non-dormant (soft) or dormant (hard) that does not respond to heat, non-arillate	Tribe Pomaderreae (more sclerophyllous) separates from Colletieae	Highly fireprone, woodland/forests	Dormant, hard, arillate, heat-stimulated dormancy breakage	50–43	Onstein & Linder (2016); Pausas & Lamont (2022); (all 32 fireprone Pomaderreae examined heat-responsive, arillate)
Ceanothus, Rhamnaceae	Africa, N America, Eurasia?	Non-fireprone rainforest (non-sclerophyllous)	Non-dormant (soft) or dormant (hard) that does not respond to heat	*Ceanothus* (sclerophyllous) separates from tribes Gouanieae and Paliureae (*Ziziphus*)	Highly fireprone, woodland/forests	Dormant, hard, heat-stimulated dormancy breakage	44–23	Onstein & Linder (2016); Pausas & Lamont (2022) (all 27 *Ceanothus* spp. examined heat responsive)
Polygalaceae, fireprone clade	Africa, S America, SE Asia	Non-fireprone rainforest in Africa, S America, SE Asia	Non-dormant (soft), non-arillate, non-soil-stored	Basal *Xanthophyllum*, *Moutabea*, *Atroxima–Carpolobia* lineages separate from derived Polygalaceae: *Polygala*, *Muraltia*	Fireprone woodland/forests	Hard, dormant, soil-stored, arillate (ant-dispersed), possibly smoke-stimulated dormancy break (trait poorly studied among fireprone members)	56.3–54	Forest *et al.* (2007) [in addition, *Comesperma* is ant-dispersed (Berg 1975) whereas *Bredemeyera* is not (Verkerke 1985)], Pastore & Abbott (2012)
Rutaceae, Amyridoideae	Africa, Australia?	Non-fireprone rainforest	Non-dormant, non-arillate, non-soil-stored, bird-dispersed	Basal tree-form *Vepris* (Africa), *Flindersia*, *Lunasia* separate from xeromorphic shrubby Boroniaeae (*Boronia*, *Zieria*) and *Eriostemon* clades	Highly fireprone sclerophyll shrubland, woodland to forests	Dormant, soil-stored, arillate, smoke-stimulated dormancy breakage	45–41	Bayly *et al.* (2013); Paetzold *et al.* (2018); Pausas & Lamont (2022) (interpretation assisted by Tianhua He)
Pathway A2. Migration from one fireprone habitat type to a crown-fire type (gains different fire-related trait)								

Pinaceae, *Pinus*	N Hemisphere	Open woodland (savanna) with surface fires	Non-dormant, non-serotinous	*Pinus*, subgenus *Pinus*	Denser forest with less frequent, intensified (crown) fires	Enforced dormancy (serotiny)	114 (stem) 84 (crown)	He *et al.* (2012); dates updated in Lamont *et al.* (2019*a*)
Proteaceae, Proteoideae	Cape, S Africa, SW Australia?	Fireprone, sclerophyll shrublands	Stored (whether in soil or canopy unclear)	*Frankandia*/ *Isopogon*/ Adenanthinae separate from rest of Proteoideae	Fireprone shrubland, intensified fire?	Soil-stored, dormancy released by smoke	80–71	Sauquet *et al.* (2009); Lamont & He (2012)
Proteaceae, Proteoideae	Cape, S Africa, SW Australia?	Fireprone, sclerophyll shrublands	Stored (whether in soil or canopy unclear)	*Petrophile*/*Aulax* separate from rest of Proteoideae	Fireprone shrubland, intensified fire?	Serotinous cones, fire-stimulated seed release	71–50	Sauquet *et al.* (2009); Lamont & He (2012)
Proteaceae, Adenanthinae	Cape, S Africa, SW Australia?	Fireprone, sclerophyll shrublands	Soil-stored, dormancy released by smoke, non-arillate	Adenanthinae separates from sisters *Isopogon*/*Franklandia*	Fireprone shrubland, intensified fire?	Soil-stored, arillate (ant-dispersed), smoke-released dormancy	45–36	Sauquet *et al.* (2009); Lamont & He (2012)
Proteaceae, *Hakea*	SW Australia	Fireprone shrub/woodland	Non-serotinous, seeds released at maturity, seeds semihard, winged in soft follicle (*Grevillea*-type)	*Hakea* separates from *Grevillea*	Highly fireprone sclerophyll shrublands/ woodlands/forest	Seeds soft, winged, serotinous – enforced dormancy in woody follicle, fire-stimulated seed release	23–18	Lamont *et al.* (2016, 2017*a*), backdated according to Austin Mast (pers. comm.)
Proteaceae, *Leucadendron*	Cape, S Africa	Fireprone shrublands	Seeds (fruits) released at maturity	*Leucadendron* separates from sisters	Fireprone shrubland, more frequent/regular fire?	Seed soft, winged (later wingless, rounded) held in serotinous cones	28–18	Lamont & He (2012); Tonnabel *et al.* (2014); Newton *et al.* (2021)
Proteaceae, *Leucadendron*	Cape, S Africa	Fireprone shrublands	Serotinous, non-arillate, enforced dormancy	Advanced *Leucadendron*, clades D and F of Tonnabel *et al*. (2014)	Fire-prone shrubland, intensified fire?	Soil-stored, arillate (ant-dispersed), smoke-released dormancy	4.9–0.35	Lamont & He (2012); Tonnabel *et al.* (2014)
Restionaceae	Cape, S Africa	Fireprone	Soil-stored, non-	Terminal genera,	Fire-prone	Soil-stored,	18–6	Linder & Vlok

		shrubland, winter wetland	arillate, smoke-released dormancy	*Ceratocaryum* to *Mastersiella*, in *Wllldenowia* clade	shrubland, winter wetland, intensified fire?	arillate (ant-dispersed), smoke-released dormancy		(1991); Brown *et al.* (1994); He *et al*. (2016)
Chloridoideae, Poaceae	(Sub)tropical regions throughout the world	Fireprone C$_3$ (often annual) grasslands	Dormant, water-permeable lacking smoke sensitivity to breaking dormancy (e.g. *Danthonia*)	Core C$_4$ clade (includes Chloridoideae) arises from C$_3$ ancestor, and/or possibly when *Eriachne* separated from Micrairoideae	C$_4$ grasslands (usually perennial) with frequent fire	Dormant, with gain of smoke sensitivity for breaking dormancy	32–25 (includes *Eragrostis*, *Sporobolus*, no ancestral trait assignment made so most likely dates and relations unclear	Edwards *et al.* (2010); Morrone *et al.* (2012); Table S2
Triodia, Poaceae	Central Australia	C$_4$ grassland, savanna	Non-dormant, smoke not required to break dormancy	*Triodia* (all spp. C$_4$) separates from other C$_4$ grasses	Hummock grasslands/ shrublands, reduction in fire frequency	Restoration of smoke sensitivity for breaking dormancy accompanies xerophytic changes	22–14.5 (no ancestral trait assignments made so most likely dates unclear)	Edwards *et al.* (2010); Erickson (2015); all, and only, 7 *Triodia* spp. examined smoke sensitive among 22 grasses; Toon *et al.* (2015)
Fabaceaae, *Daviesia*	SW Australia	Fireprone shrubland to forest	Immediate ancestor of *Daviesia* hard-seeded but non-arillate	*Daviesia* separates from nearest relative	Shrubland/ woodland under intensifying fire	Hard seed, arillate	33–27	Cook *et al.* (2015); Crisp *et al.* (2017); Lamont & He (2017*b*)
Fabaceae, Mimosoideae	Australia	Fireprone forests	Hard, heat-released dormancy, non-arillate, e.g. *Albizia* (Asia)	*Acacia* (99% of species)	Highly fireprone sclerophyll shrubland to forest	Hard seed, heat-released dormancy, arillate [ant- and (later) bird-dispersed]	28–24.5	Gunn (1984); O’Dowd & Gill (1986); Miller *et al.* (2013); Milne (1988)
Closest *Lupinus* ancestors	Mediterranean Basin	Fireprone shrublands	Hard testa as in sister *Genista* (Genisteae), dormancy not heat-released	*Lupinus* arises from *Genista*-type ancestor	Fireprone shrublands	Hard seed retained, dormancy heat released	17–11.5, e.g. *L. hirsutissimus* one of oldest species at 9 Ma	Keeley & Keeley (1986); Eastwood *et al.* (2008)
Pakaraimaea–	Africa–S America?	Fireprone forest-	Hard testa, fire-type	*Pakaraimaea*	*Pakaraimaea*	Hard testa, fire-	42	Thanos *et al.* (1992);

Cistaceae	(possibility of Gondwanan link undergoing research)	woodland	heat-released dormancy	(monotypic) and Cistaceae separate from common fireprone ancestor	remains in monsoon forest, S America, Cistaceae migrates to highly fireprone forest–woodland, Africa	type heat-released dormancy, thicker and deeper plug in Cistaceae, intensfied fire as Cistaceae migrated into more open vegetation?	(Heckenhauer *et al*., 2017), 35–23 (Aparicio *et al*. 2017) – both much too young and more likely >105 Ma, before Africa–S America separated	Nandi (1998); Aparicio *et al.* (2017); Heckenhauer *et al.* (2017); B. Lamont, A. Thornhill & D. Korczynskyj (unpublished data)
Pathway B1. Migration from crown-fire-type habitat to surface-fire-type habitat (loss of fire-related trait)								
Pinus, subgenus *Pinus*	N Hemisphere	Dense forest with intense (crown) fires	Serotinous cones, wind-dispersed, enforced dormancy	9 terminal species/lineages in subgenus *Pinus*	Savanna woodlands or grasslands	Non-serotinous cones, non-dormant, wind-dispersed	41–1	He *et al.* (2012)
Cistaceae	Mediterranean Basin	Fireprone shrublands to forests	Hard seed, heat-released dormancy, perennial subshrubs	*Helianthemum salicifolium*	Fireprone, decreased fire frequency	Hard seeded, but does not respond to fire-type heat, annual herb	1.0	Thanos *et al.* (1992); Yeşilyurt *et al.* (2017); Aparicio *et al.* (2017)
Proteaceae, *Banksia*	N Australia	Crown-fireprone woodland	Enforced dormancy (serotinous), heat release	Advanced *Banksia*, e.g. *Banksia dentata*	Grassy savannas, fireprone, frequent spring fires	Non-dormant (non-serotinous)	12–8.5	He *et al.* (2011); Lamont & He (2017*b*)
Salomonia, Polygalaceae	N Australia and China	Crown-fireprone woodland/forest	Hard, dormant, soil-stored, arillate (ant-dispersed), possibly smoke-stimulated germ	*Salomonia* separates from *Polygala*	Grassy savannas, fireprone, frequent spring fires	Hard, dormant, soil-stored, non-arillate (mammal-dispersed), non-fire-stimulated germination	37.3–2.7	Pastore *et al.* (2019); Forest *et al.* (2007)
Proteaceae, *Protea*	N and NE Cape, S Africa	Moderate fire intervals	Enforced dormancy (serotinous), heat released	Grassland proteas, e.g. *Protea rubropilosa*	Savanna grasslands	Non-dormant (non-serotinous)	137, 42	Lamont *et al.* (2013); Lamont *et al.* (2017*b*)
Lupinus	SE USA, Florida	Woodland, moderately fireprone	Hard testa, dormancy heat-released	Advanced lupins: *L. diffusus* (syn. *L. cumulicolus)*	Savanna pine woodland, frequent fire	Hard testa, killed at 90°C, dormancy only	0.3	Eastwood *et al.* (2008); Campbell-Martínez *et al.*

						released by scarification		(2019)
Andropogoneae, Paniceae, Poaceae	C_4 grasslands throughout the world	C_4 grasslands moderately fireprone	Dormant, with smoke sensitivity for breaking dormancy	Genera such as *Cymbopogon*, *Andropogon* and other more advanced lineages lose smoke sensitivity	e.g. 50% of C_4 spp. in eucalypt forest are smoke sensitive, but 25% in frequently burnt grasslands	Dormant with loss of smoke sensitivity (some other process breaks dormancy), or non-dormant	22–17 (no ancestral trait assignments so most likely dates and relations unclear)	Edwards *et al.* (2010); Lamont *et al.* (2019b); Pausas & Lamont (2022)
Pathway B2. Migration from moderately burnt (crown-fire) habitat to non-fireprone habitat (loss of fire-related trait)								
Fabaceae, *Acacia*	Central Australia	Sclerophyll shrubland to wet forest, strongly fireprone	Hard seeds, heat-released dormancy, arillate (ant-dispersed)	*Acacia* (about 8 spp.), e.g. *A. oswaldii*	Non-fireprone or rarely burnt	Soft seeds, non-arillate	6.4–4.9 (*Acacia oswaldii* lineage)	O'Dowd & Gill (1986); Miller *et al.* (2013); Murphy *et al.* (2010); Burrows *et al.* (2018)
Pinus, subgenus *Pinus*	N Hemisphere	Dense forest with intense (crown) fires,	Serotinous cones, wind-dispersed, enforced dormancy	9 terminal species/lineages in subgenus *Pinus*	Non-fireprone, subalpine woodland	Non-serotinous cones, non-dormant, wind-dispersed	41–1	He *et al.* (2012)
Proteaceae, Proteoideae	Australia, Queensland	Fireprone, sclerophyll forest on poorer, drier soils	Stored (whether soil or canopy unclear as 50% probability for each)	*Eidothea* in Australia separates from early Proteoideae	Rainforest, non-fireprone (note: lineage returns to rainforest)	Vertebrate-dispersed drupes, hard endocarp that splits with time	95–85 (separation updated by T. He, unpublished)	Lamont & He (2012); Pausas & Lamont (2018)
Pinus, subgenus *Strobus*	N Hemisphere	Open woodland (savanna) with surface fires	Non-dormant, non-soil-stored, winged wind-dispersed	10 species/lineages in subgenus *Strobus*	Rarely burnt or non-fireprone upland forest or woodland	Dormant, thick-walled, soil-stored, wingless bird-dispersed	47–1	Lamont *et al.* (2019*a*)
Cistaceae	Mediterranean Basin	Fireprone shrubland to forest	Hard seed, heat-released dormancy	*Helianthemum hirtum*, *H. syriacum*, *H. almeriense*, *H. appeninum*	Non-fireprone limestone/gypsum outcrops	Remain hard seeded, but unresponsive to fire-type heat or inhibited	< 1.9	Thanos *et al.* (1992); Aparicio *et al.* (2017); Pérez-García & González-Benito (2006)
Cistaceae	Mediterranean	Fireprone shrubland	Hard seed, heat-	*Helianthemum*	Non-fireprone	Soft or hard	< 1.9	Thanos *et al.* (1992);

	Basin	to forest	released dormancy	*lippii*, *H. polygonoides*	salt-lake dunes and marshland	seeded, but does not respond to fire-type heat		Aparicio *et al.* (2017); Zaman *et al.* (2009), Copete *et al.* (2009)
Ericaceae, *Erica coccinea*	S Africa, Cape	Fireprone shrubland	Smoke-released dormancy, broad incubation temperatures (pyrophyte)	Ecotype change	Non-fireprone (rock outcrop)	Non-dormant, lower incubation temperatures optimal (pyrofuge)	Quaternary?	Leonard *et al.* (2018)
Fabaceae, Faboideae	NE Australia	Fireprone forest	Hard seed, heat-released dormancy	*Castanospermum australe*	Rainforest, non-fireprone	Recalcitrant (non-dormant)	Quaternary?	Lamont *et al.* (2019*b*); Marques *et al.* (2019)
Fabaceae, Mimosoideae	Various locations	Fireprone forest	Hard seed, heat-released dormancy	*Mariosousa*, *Mimosa*, *Adenanthera*	Non-fireprone	Soft seed, non-dormant (seed killed by fire-type heat)	7 (*Mariosousa willardiana*), 4 (*Mimosa pteridifolia*), 11 (*Adenanthera*)	DeBouck *et al.* (1993); Bouchenak-Khelladi *et al.* (2010); Daibes *et al.* (2019); Lamont *et al.* (2019*b*)
Goodeniaceae, *Scaevola*	Pacific Ocean coastline	Fireprone shrub/woodland	Soil-stored, smoke-released dormancy	Advanced *Scaevola*	Non-fireprone	Non-fire-released dormancy		Roche *et al.* (1997); Jabaily *et al.* (2014)
Lamiaceae, *Prunella vulgaris*	?	Fireprone grassland	Soil-stored, fire-released dormancy	Ecotypic change	Non-fireprone	Non-fire dormancy breakage		Clark & Wilson (2000); Godoy *et al.* (2011)
Proteaceae, *Hakea*	SW Australia	Fireprone shrub/woodland	Enforced dormancy (serotinous), heat release	Advanced *Hakea*, e.g. *Hakea clavata*	Non-fireprone	Non-dormant (non-serotinous)	9–6	Lamont *et al.* (2017*a*)
Lupinus	Savanna, Texas–Mexico	Savanna woodland	Hard testa, dormancy heat-released	Advanced lupins: *L. texensis*	Non-fireprone	Non-dormant (95% germ), suppressed at 85°C (38%)	1.2–0.4	Davis *et al.* (1991); Eastwood *et al.* (2008); Pausas & Lamont (2022)
Lupinus	NE Africa (Egypt) – saline margins of Nile River	Fireprone shrublands	Hard testa, dormancy heat-released	Advanced lupins: *L. alba* ssp. *termis*	Non-fireprone, halophytic (tolerates up to 200 mM salt)	Non-dormant (100% germination untreated)	0.5 (*Lupinus alba*)	Shaddad *et al.* (1990); Eastwood *et al.* (2008); Pausas & Lamont (2022)

Polygala, Polygalaceae	China and India	Fireprone woodland/forest	Hard, dormant, soil-stored, arillate (ant-dispersed)	*Polygala arillata* separates from rest of *Polygala*	Non-fireprone	Hard, dormant, fleshy aril wraps around seed – bird-dispersed, not fire-stimulated germination	32.8–27.9	https://indiabiodiversity.org/species/show/17434; Forest *et al.* (2007)
Rutaceae, Amyridoideae	Australia and Pacific islands	Fireprone sclerophyll shrubland, woodland to forest	Hard, dormant, soil-stored, elaiosome (ant-dispersed), smoke-stimulated dormancy breakage	Xeromorphic shrubby Boroniaeae (*Boronia*, *Zieria*) separate to give *Acronychia*/*Melicope* clade	Non-fireprone	Non-dormant, non-arillate, non-soil-stored, bird-dispersed	<40–13 (highly tentative as Boroniaeae not included in Paetzoid's chronogram so diversion could begin anywhere around 40–13 Ma period)	Bayly *et al.* (2013); Paetzold *et al.* (2018); Pausas & Lamont (2022)

[#] Should the preliminary evidence that the Australian clade is also ancestrally smoke-stimulated be confirmed, this would push smoke sensitivity among Restionaceae back to 110–70 Ma.

Table S8. List of references used to construct Fig. 9, with additional information. NZ = New Zealand, MB = Mediterranean Basin.

Code	Reference	Species	Region	Summer treatment	Fire treatment
1	Moreira & Pausas (2012)	5 Cistaceae species and 1 Fabaceae; several populations of each species	Spain, Turkey	Temperature fluctuations (18 to 43 °C) for 1 months	120 °C for 5 min
2	Luna (2020)	12 Cistaceae species	Central Spain	Average of 4 treatments: 50 °C* and 20/50 °C, for 1 and 2 months	100 °C for 10 min
3	Ooi *et al.* (2014)	12 Fabaceae species	Australia	20/40 °C for one month	80 °C for 10 min
4	Newton *et al.* (2021)	5 *Leucadendron* species (Proteaceae)	South Africa	20/40 °C for one month	80 °C for 20 min
5	Elliot *et al.* (2011)	2 *Lupinus* species (Fabaceae)	USA	37 °C for 8 min	80 °C for 7 min
6	Haines *et al.* (2007)	2 *Pomaderris* species (Rhamnaceae)	NZ	60 °C for 30 min	Boiling water allowed to soak to ambient
7	Karaguzel *et al.* (2004); Quinlivan (1968)	*Lupinus varius*	MB	15/40 °C for 2 months	Boiling water for 4 min
8	Tieu *et al.* (2001)	*Anigozanthos manglesii*, *Gompholobium knightianum*	Australia	50 °C* for 6 weeks	120 °C for 10 min
9	Hall *et al.* (2017)	*Acacia saligna*, *Phylica cephalantha*, *Trichocephalus stipularis*, *Thamnochortus punctatus*, *Pelargonium elongatum*	South Africa	20/40 °C for 2 months	100 °C for 2.5 min
10	Mbalo & Witkowski (1997)	*Acacia* (*Vachellia*) *karoo*, *A.* (*V*). *tortilis*	African savanna	50 °C* for 2 weeks	100 °C for 1 min
11	Zupo *et al.* (2016)	*Mimosa leicocephala*	Brazilian savanna	15/50°C for 1 month	25 °C to 80 °C in 10 min, back to 25 °C in 1 h
12	Gorgone-Barbosa *et al.* (2016)	*Urochloa decumbens*, *U. brizantha*	Brazilian savanna	10/40 °C for 1 month	50 °C for 20 min
13	Zhang *et al.* (2020)	*Melilotus albus*	W China savanna	Maximum value observed among untreated seeds under field conditions (their Fig. 6)	95 °C for 1 and 10 min (mean)

*Note that summer treatment of continuous 50 °C for one or more months (Luna, 2020; Mbalo & Witkowski, 1997; Tieu *et al.*, 2001) are much too high to simulate temperature conditions in the soil seed bank over summer in the absence of bare areas after fire according to Brits (1986), Auld & Bradstock (1996), Merritt *et al.* (2007) and Baeza & Roy (2008); thus the summer germination value in Fig. 9 for these species is probably too high as it approaches conditions more associated with fire.

Appendix S2. Timing of germination (seasonality effects)

The timing of germination depends on (*a*) the type of fire regime (crown or surface fires), (*b*) the interplay between the season in which fire occurs and the season(s) in which germination is possible, and (*c*) the extent to which dormancy is controlled by internal (primary) or external (secondary) factors. Table S9 provides a simplified account of the process; there will be plant communities for which this model will need adjusting.

In the absence of fire, dormancy is maintained by embryo maturation (not considered here), seed hardness and the availability of specific chemical cofactors. Priming may sometimes occur *via* cold (winter) or warm (summer) stratification but rarely by exposure to light (if dormancy is dark maintained). Decay and scarification processes may gradually render some seeds permeable to water and oxygen. This could lead to limited germination but dormancy will remain imposed by the dry soil and/or low (winter) or high (summer) temperatures. Thus, germination is negligible even among the few non-dormant seeds until the soil becomes moist again, and the temperature falls (crown-fire ecosystems) or rises (surface-fire ecosystems) to moderate levels. Not until fire has occurred is there any primary dormancy release – widespread and almost universal in crown-fire habitats but limited and taxonomically restricted in surface-fire habitats. Fire-type heat and smoke are highly effective in crown-fire ecosystems (Figs 2, 3, 5, 9), with minor responses to the greater availability of light (Fig. S6). Heat and smoke are on average half as effective at promoting germination in surface-fire ecosystems, partly because dormancy levels are lower (Figs 5, S8, Table S4). For crown-fire systems, following a delay after fire (lightning-caused historically, but mostly anthropogenic today) of 3–8 months (Enright & Lamont, 1989; rarely 12 months or more, Zhang *et al*., 2020), conditions become suitable for germination in winter and secondary dormancy is annulled. The landscape is flooded with spring seedlings, mostly from species killed by fire (Lamont & Wiens, 2003; Lamont & Witkowski, 2021) in crown-fire ecosystems depending on fire intensity and patchiness (Fig. S2; He *et al*., 2019). A spring peak is less noticeable in surface-fire ecosystems as germination is spread more evenly through the year because (*a*) most seeds are heat tolerant but dormancy is less likely to be released by fire so that the postfire flush of seedlings is meagre; (*b*) many non-dormant seeds germinate independently of fire, perhaps responding to exceptionally wet, cool or warm periods that minimize enforced dormancy, (*c*) germination can occur immediately after fire if the soil is still moist (autumn following summer rain), or after a delay during the dry winter until the following spring when conditions are warm and rains start to return (Zhang *et al*., 2020), (*d*) the large fraction of dormant seeds that do not exhibit fire-released dormancy but gradually lose their inherent dormancy with time, and (*e*) the predominance of resprouters, meaning that individual plants produce few seeds, and thus few seedlings, compared with non-resprouters (Lamont & Witkowski, 2021), and have low viability, e.g. 10% of legumes in the Cerrado (Fig. S8A).

Table S9. Summary of seasonal aspects of maintaining and breaking seed dormancy in three major biome types with contrasting fire regimes over 30 months, with one fire in crown-fire ecosystems [spring (sp), summer (su) or autumn (au)] and two fires in surface-fire ecosystems (first in sp or su, second in sp or au). Mediterranean and uniform-rainfall temperate climate biomes are combined as their dormancy patterns are similar (peak fires tend to occur in late autumn in the former and late spring in the latter). The various steps are supported by van Klinken *et al*. (2006), Merritt *et al*. (2007), King & Menges (2018), Hodges *et al*. (2019), Luna (2020), Zhang *et al*. (2020), and Figs 2, 3, 5, 9, S2, S4, S6, S8. Note that primary dormancy may be broken but germination is prevented by secondary dormancy; also that additive and synergistic effects are not represented in this scheme − see main text and Supplementary figures as indicated for more details. Some steps are extrapolated and lack direct evidence at present. It is assumed that light is most likely to be available after fire but soil disturbance is an alternative cause. Note that warm stratification (Merritt *et al*., 2007) is equivalent to greater diurnal temperature fluctuations as may occur after fire or in bare areas (Brits, 1986).

Mediterranean or uniform rainfall (temperate, high-fuel, summer-dry ecosystems), crown (woody plants) fires									
Year	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**3**
Season	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
Fire	No fire	No fire	No fire	Crown fire (or su–au)	Crown fire (or sp, au)	Crown fire (or sp–su)	No fire	No fire	No fire
Soil	Dry or drier	Becoming moist	Moist	Becoming dry	Dry or drier	Becoming moist	Moist	Becoming dry	Dry or drier
Plant	Seed release (or stored on plant)	Seed soil storage	Seed soil storage	Flowering, or seed release by fire	Seed release naturally or by fire	Seed release naturally or by fire	Seed soil storage	Flowering promoted or retarded	Seed release
Internally controlled dormancy	Imposed morphologically, physically, or physiologically	Imposed morphologically, physically, or physiologically	Imposed morphologically, physically, or physiologically	Imposed morphologically, physically, or physiologically (if escapes fire effects)	Imposed morphologically, physically, or physiologically (if escapes fire effects)	Imposed morphologically, physically, or physiologically (if escapes fire effects)	Imposed morphologically, physically, or physiologically	Imposed morphologically, physically, or physiologically	Imposed morphologically, physically, or physiologically
Externally controlled dormancy	Imposed by drought, high temperatures, dark (if broken by light)	Imposed by drought, high temperatures, dark (if broken by light)	Imposed by low temperatures, dark (if broken by light)	Imposed by drought, high temperatures (can reimpose dormancy after fire[1]), dark (if broken by light)	Imposed by drought, high temperatures (can reimpose dormancy after fire[1]), dark (if	Imposed by drought, high temperatures (can reimpose dormancy after fire[1]), dark (if	Imposed by low temperatures, dark (if broken by light)	Imposed by drought, high temperatures, dark (if broken by light)	Imposed by drought, high temperatures, dark (if broken by light)

					broken by light)	broken by light)			
Dormancy broken by	Warm/dry stratification, maturation or decay	Warm/wet[2] or dry stratification, maturation or decay	Cold/wet stratification, maturation or decay	Heat, smoke chemicals, charates, ash, light and/or non-fire factors	Heat, smoke chemicals, charates, ash, light and/or non-fire factors	Heat, smoke chemicals, charates, ash, light and/or non-fire factors	Cold/wet stratification, maturation or decay	Warm/wet[2] or dry stratification, maturation or decay	Warm/wet[2] or dry stratification, maturation or decay
Germination (stored)	Nil	Nil	Nil	Nil	Nil	Some germination	**Peak** (*en masse*) germination (unless rain biseasonal)	Some germination	Nil
Non-dormant (not stored)	Dormancy imposed by drought, high temperatures	Some germination	**Peak** germination (unless rain biseasonal)	Some germination	Dormancy imposed by drought, high temperatures	Some germination	**Peak** germination (unless rain biseasonal)	Some germination	Dormancy imposed by drought, high temperatures
Seed mortality (stored and non-stored)	High (heat)[3]	High (heat)	Low (decay)	Moderate (decay)	High (heat)	High (heat)	Low (decay)	Moderate (decay)	High (heat)

Savannas (tropical or subtropical, low-fuel, summer-wet ecosystems), surface (grasses) fires

Year	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**3**
Season	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
Fire	No fire	Surface fire (or sp)	No fire	Surface fire (or au)	No fire	Surface fire (or sp)	No fire	Surface fire (or au)	No fire
Soil	Moist	Becoming dry	Dry	Becoming moist	Moist	Becoming dry	Dry	Becoming moist	Moist
Plant	Flowering and seed release	Seed release and storage	Seed soil storage	Some flowering	Flowering, especially in response to fire	Seed release naturally or by fire	Seed soil storage	Flowering promoted or retarded	Seed release

Internally controlled dormancy	Imposed morphologically, physically, or physiologically	Imposed morphologically, physically, or physiologically (if escapes fire effects)	Imposed morphologically, physically, or physiologically	Imposed morphologically, physically, or physiologically (if escapes fire effects)	Imposed morphologically, physically, or physiologically	Imposed morphologically, physically, or physiologically (if escapes fire effects)	Imposed morphologically, physically, or physiologically	Imposed morphologically, physically, or physiologically (if escapes fire effects)	Imposed morphologically, physically, or physiologically
Externally controlled dormancy	Imposed by (wet) heat[4], dark (if broken by light)	Imposed by (wet) heat[4], dark (if broken by light)	Imposed by drought, low temperatures, dark (if broken by light)	Imposed by (wet) heat[4], dark (if broken by light)	Imposed by (wet) heat[4], dark (if broken by light)	Imposed by (wet) heat[4], dark (if broken by light)	Imposed by drought, low temperatures, dark (if broken by light)	Imposed by (wet) heat[4], dark (if broken by light)	Imposed by (wet) heat[4], dark (if broken by light)
Dormancy broken by:	Warm/wet[5] stratification, maturation or decay	Heat, smoke chemicals, charates, ash, light and/or non-fire factors	Cold/dry stratification or maturation	Heat, smoke chemicals, charates, ash, light and/or non-fire factors	Warm/wet[5] stratification, maturation or decay	Heat, smoke chemicals, charates, ash, light and/or non-fire factors	Cold/dry stratification or maturation	Heat, smoke chemicals, charates, ash, light and/or non-fire factors	Warm/wet[5] stratification, maturation or decay
Germination (stored)	Little germination	Some germination	Nil	Some germination (some delayed from previous fire[6]) (**peak**)	Little germination	Some germination	Nil	Some germination (some delayed from previous fire[6]) (**peak**)	Little germination
Non-dormant (not stored)	Some germination	Some germination	Dormancy imposed by drought, low temperatures	Some germination (**peak**)	Dormancy imposed by high temperatures	Some germination	Dormancy imposed by high temperatures	Some germination (**peak**)	Dormancy imposed by drought, low temperatures
Seed mortality (stored and non-stored)	High (heat, decay)	High (heat, decay)	Low	Moderate (decay)	High (heat, decay)	High (heat, decay)	Low	Moderate (decay)	High (heat, decay)

1, Luna (2020), Lamont & Witkowski (2021); 2, Merritt *et al*. (2007), Hodges *et al*. (2019); 3, Enright & Lamont (1989); 4, King & Menges (2018); 5, van Klinken *et al*. (2006); 6, Zhang *et al*. (2020).

Table S10. Smoke-stimulated germination in rainforest species. Family affiliations of 52 species in rainforests subjected to seed smoke pretreatments and their responses compared with seed-dormancy-breaking requirements in other members of the same family that occur in fireprone ecosystems. While *Acacia disparrima* and *A. melanoxylon* (Fabaceae) occur in Queensland rainforest, they also occupy sclerophyll forests, and are the only species in this table likely to be ant-dispersed according to the taxonomic distribution of elaiosomes given in Berg (1975) and Lengyel *et al*. (2010).

Family of species in rainforest	**Species in rainforest smoke-responsive? (no. spp. > 1)**	**Smoke-responsive in other ecosystems?**	**Germination stimuli for rainforest species**	**Germination cues for non-rainforest species**	**Supporting reference for smoke-responsiveness**
Melastomataceae	no (2)	yes	?	light	Ferraz *et al.* (2013); Liang *et al.* (2020)
Malvaceae	no (2)	yes	scarification[1]	heat	Ferraz *et al.* (2013); Baker *et al.* (2005)
Bignoniaceae	yes	no/yes (*Jacaranda copeia*)	smoke (*Jacaranda copeia*), non-dormant	light	Ferraz *et al.* (2013); Liang *et al.* (2020)
Boraginaceae	no (2)	yes	non-dormant	not required	Ferraz *et al.* (2013); Stevens *et al.* (2007)
Fabaceae	no (5)	no (rarely yes)	Scarification[2], non-dormant	heat	Ferraz *et al.* (2013); Liang *et al.* (2020); Smith *et al.* (2008)
Lecythidaceae	no (2)	no	non-dormant, ?	not required	Ferraz *et al.* (2013); Liang *et al.* (2020)
Meliaceae	No (inhibited)	yes	non-dormant, ?	not required	Ferraz *et al.* (2013); Roeder *et al.* (2019)
Commelinaceae	no (2)	no	non-dormant	not required	Carthey *et al.* (2018)
Cunoniaceae	no	yes	?	?	Carthey *et al.* (2018)
Cyperaceae	no (2)	yes	?	?	Carthey *et al.* (2018)
Solanaceae	no	yes	?	?	Carthey *et al.* (2018)
Acanthaceae	no	yes	?	?	Konsam *et al.* (2017)
Rosaceae	no	yes	?	?	Baldwin & Morse (1994)
Vitaceae	no	yes	?	?	Tsuyuzaki & Miyoshi (2009)
Araliaceae	no	yes	?	?	Erickson (2015)
Plantaginaceae	no	yes	?	?	Tavşanoglu *et al.* (2017)
Proteaceae	no (3)	yes	scarification, non-dormant	not required	Roche *et al.* (1997)
Anarcardiaceae	no (2)	yes	non-dormant	heat	Smith *et al.* (2008)
Combretaceae	no	yes	non-dormant	?	Smith *et al.* (2008)
Elaeocarpaceae	no (2)	yes	non-dormant	heat	Smith *et al.* (2008)
Icacinaceae	no	yes	non-dormant	?	Smith *et al.* (2008)
Pittosporaceae	no	yes	?	?	Dixon *et al.* (1995)
Rutaceae	no (2)	yes	scarification, non-dormant	?	Hopkins & Graham (1987); Smith *et al.* (2008); Liyanage *et al.* (2020)
Sapindaceae	no	no	?	heat	Smith *et al.* (2008)
Sterculiaceae	no	yes	?	?	Dixon *et al.* (1995)
Ulmaceae	no	?	?	?	Smith *et al.* (2008)
Myrtaceae	no	yes	non-dormant	?	Cochrane *et al.* (2001)
Poaceae	no	yes	non-dormant	?	Read *et al.* (2000)
Rubiaceae	no (2)	yes	?	?	Tang *et al.* (2003)
Thymelaeaceae	no	yes	?	?	Tang *et al.* (2003)
Apiaceae	no	yes	non-dormant	?	Tang *et al.* (2003)

Asclepiadaceae	no	yes	?	?	Mojzes & Kalapos (2015);
Asteraceae	no	yes	non-dormant	?	Tang *et al.* (2003)
Brassicaceae	no	yes	non-dormant	?	Mojzes & Kalapos (2016)
Moraceae	no (2)	?	non-dormant	?	Tang *et al.* (2003)

[1] *Ochroma pyramidale* benefitted from smoke water at 1:250 but not at higher or lower dilutions after scarification (Ferraz *et al.*, 2013)

[2] *Enterolobium schomburgkii* and *Schizolobium amazonicum* did not benefit from smoke after scarification (Ferraz *et al.*, 2013)

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