Effects of ponderosa pine litter smoke on sprouting in species native to ponderosa pine forests in Northern Arizona, USA

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Historic application of smoke ecology

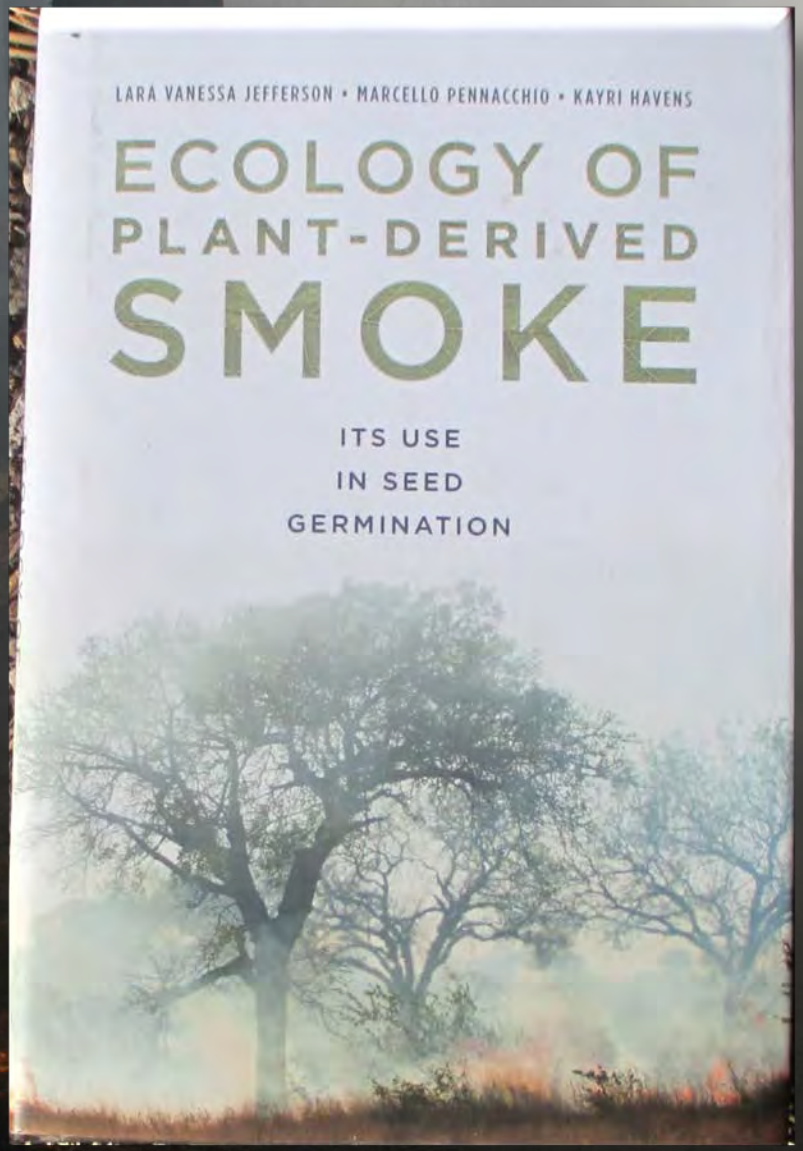
- One of the earliest known uses of smoke was as a fertility charm.
- Peasant farmers in Germany and the Great Brittan believed smoke wafting over their crops foretold a bountiful harvest
- A sect of the Zulu people of South Africa held similar beliefs, and burned several species of plants as part of this practice.
- As early as 1632, in France, there is evidence of seeds being treated with smoke prior to sowing.
- In the early 1600's, French explorers documented Huron people suspending 'germination boxes', lined with multiple layers of soil and pumpkins seeds above fires in the smoke, to increase sprouting.
- Smoke-over-fire storage is currently used by native subsistence farmers in South Africa to improve germination and seedling vigor in corn.
- In Guatemala, smoke was used to fumigate seeds.

20th century studies

- 1977: First scientific data clearly *linking* smoke and germination. Chaparral species treated with burned plant stem segments germinated, while noting that the *ash* of incinerated stem segments had no effect.

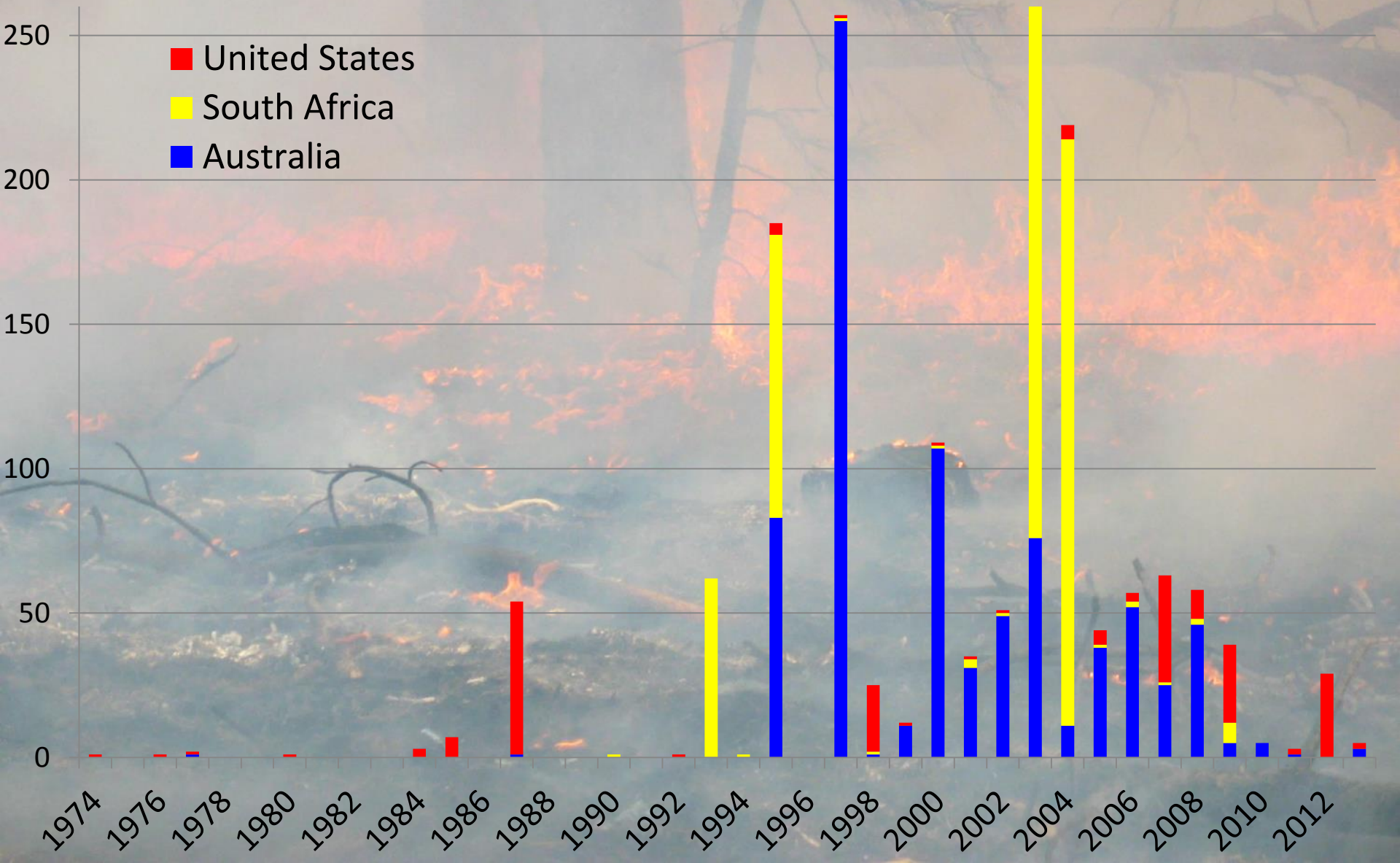
- First real use of smoke as a germination cue not until 1990. South Africa study showing germination of specific species was “significantly promoted” by smoke.

Fall 2014: First book ever on Smoke Ecology!

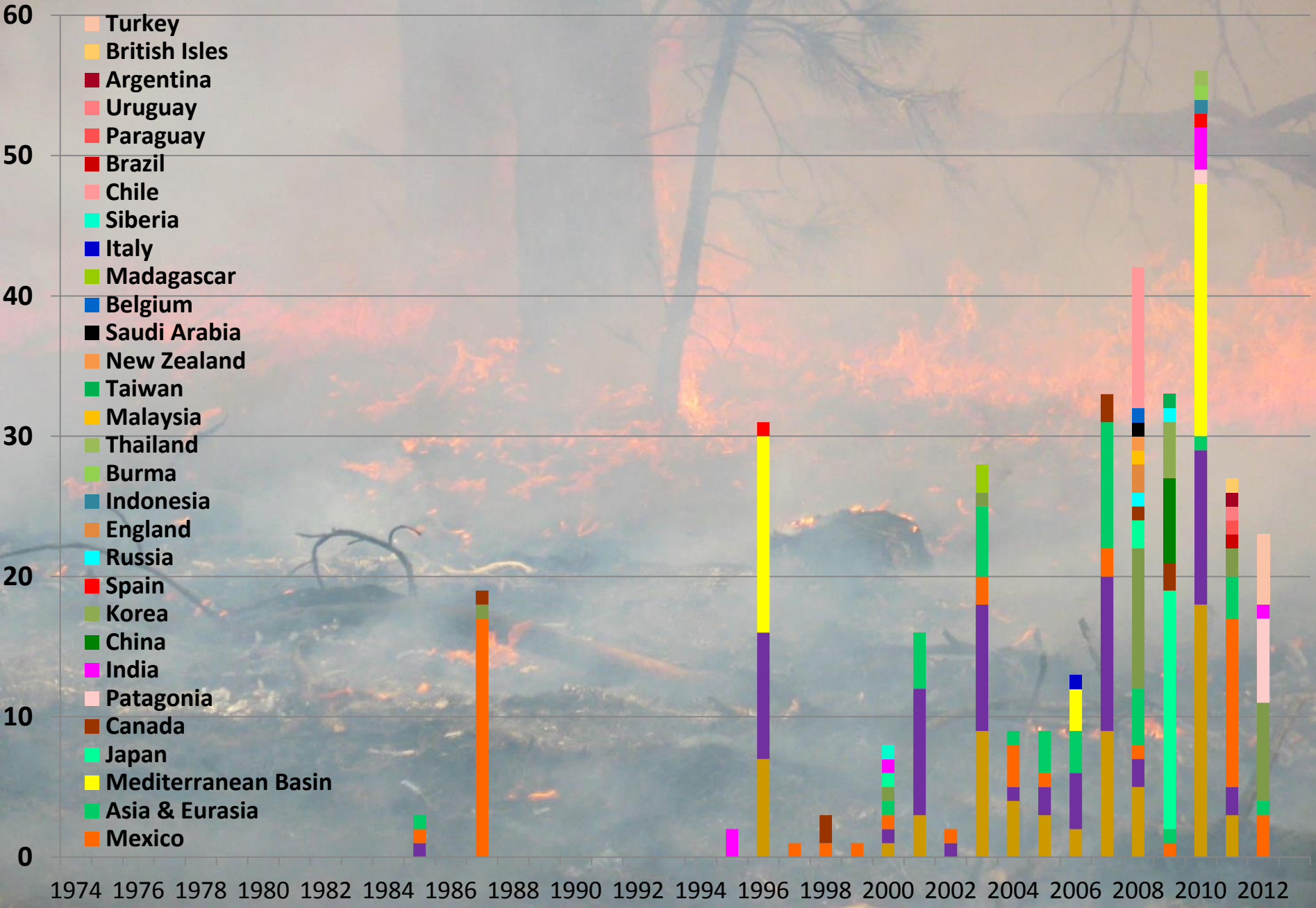


The Book summarizes 1,355 plant species whose seed have been tested for their response to smoke and it's products, and reviews the known science.

Smoke Ecology studies by species, showing the three most prolific countries



Studies in the rest of the world



+ = positive	- = inhibitory	? = not tested/known		N = no effect				
			Effects from smoke			Native?		
Genus	species	Common name	Aerial	Aqueous	Other	NM	AZ	Form
Adenostoma	*fasciculatum*	Chamise	?	+	?	N	N	Shrub
Amorpha	*canescens* Pursh	Leadplant	N	?	?	N	Y	Shrub
Andropogon	*gerardii* Vitman	Big Bluestem	N	?	?	Y	Y	Grass
Arceuthobium	*americanum*	American Dwarf mistletoe	-	?	?	N	N	Shrub
Arceuthobium	*cyanocarpum*	Limber Pine Dwarf mistletoe	-	?	?	N	N	Shrub
Arceuthobium	*vaginatum*	Pineland Dwarf mistletoe	-	?	?	Y	Y	Shrub
Arnoglossum	*atriplicifolium*	Pale Indian plantain	N	?	?	N	N	Forb
Artemisia	*ludoviciana*	White Sage	?	+	?	Y	Y	Shrub/Forb
Asclepias	*tuberosa* L.	Butterfly Milkweed	N	?	?	Y	Y	Forb
Astragalus	*crassicarpus*	Groundplum milkvetch	?	+	?	Y	Y	Forb
Astragalus	*canadensis* L.	Canadian milkvetch	+	?	?	Y	N	Forb
Baptisia	*australis* (L) R. Br. Ex Ait.f.	Blue Wild Indigo	N	?	?	N	N	Forb
Boltonia	*decurrens*	Claspiongleaf Doll's Daisy	N	?	?	N	N	Forb
Bouteloua	*curtipendula*	Sideoats Grama	+	?	?	Y	Y	Grass
Bouteloua	*gracilis*	Blue Grama	+	?	?	Y	Y	Grass
Bouteloua	*eriopoda*	Black Grama	N	?	?	Y	Y	Grass
Ceanothus	*americanus* L.	New Jersey Tea	+	?	?	N	N	Shrub
Chasmanthium	*latifolium* (Michx.) Yates	Indian Wood Oats	N	?	?	Y	Y	Grass
Coreopsis	*tinctoria*	Golden Tickseed	?	-	?	Y	Y	Forb
Coreopsis	*basalis*	Goldenmane Tickseed	+	?	?	N	N	Forb
Coreopsis	*lanceolata*	Lanceleaf Tickseed	+	?	?	Y	N	forb
Dalea	*purpurea* Vent.	Purple Prairie Clover	N	?	?	Y	Y	Forb
Dendromecon	*rigida L.*	Tree Poppy	+	?	?	N	N	Shrub/Tree
Dicentra	*chrysantha*	Golden Eardrops	+	?	?	N	N	Forb
Digitaria	*cilaris*	Introduced crabgrass (not native)	?	-	?	N	N	Grass

Dormancy

Physical: Temperature can be fire related

Mechanical: (not usually fire related)

Chemical: Smoke and other combustion products

Smoke exposure

- Aerial or liquid
- “Smoke and it’s products”

Sources of smoke/smoke products

- Coarse Woody Debris
- Litter
- Duff
- Canopy Fuels

Chemicals that Affect Germination

- ‘Inhibitory’ compounds can usually be rinsed off with water
- ‘Promoters’ appear to be irreversible once induced.
- …hypothesis – may be a mechanism that prevents seed germination from occurring until there is sufficient rainfall for species to grow and establish

Multiple Cues

Germination cues include (but are not limited to):

- Cold stratification
- Warm stratification
- Physical scarification
- Soil storage
- Heat shock

Multiple Cues

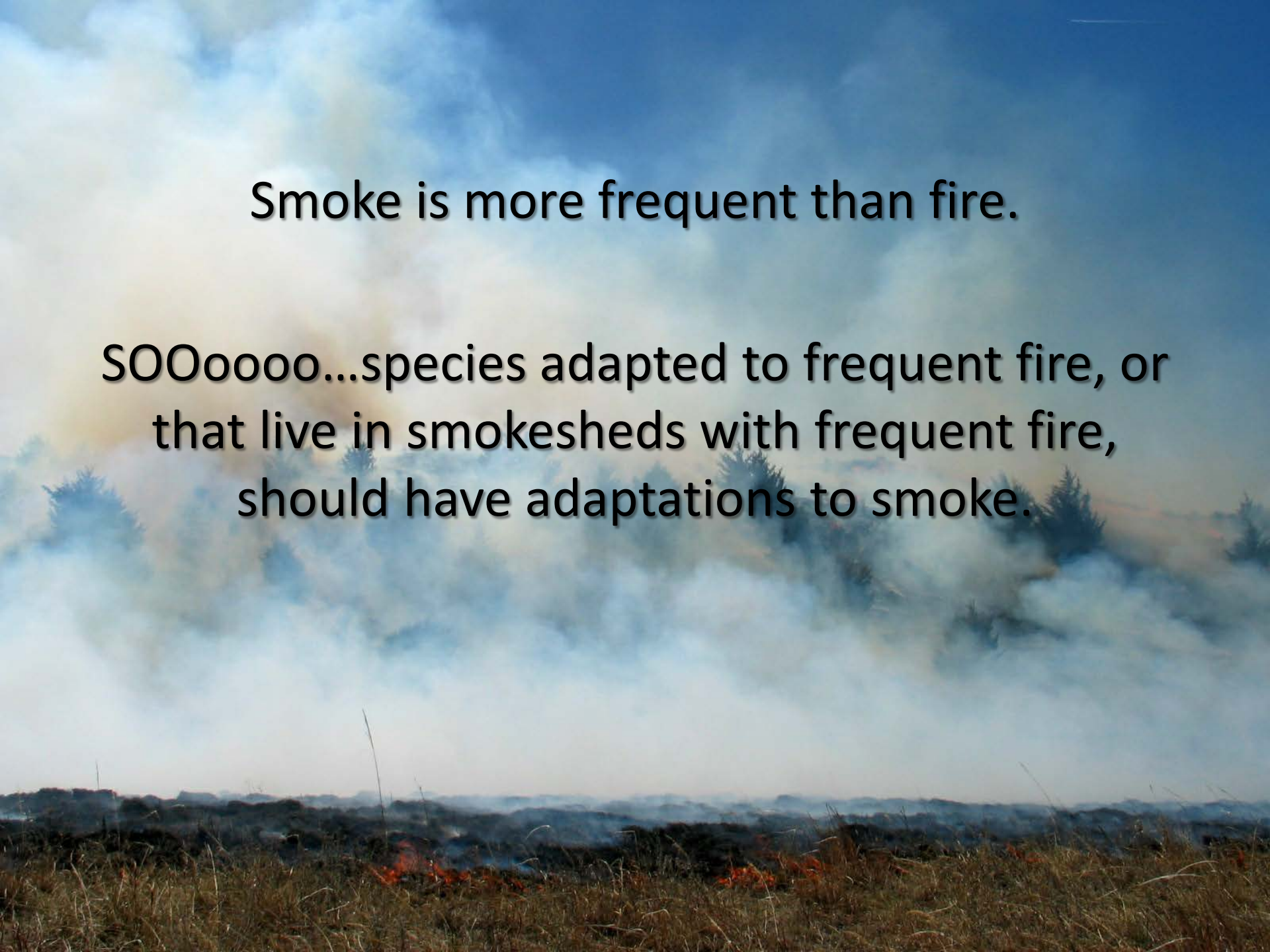
The number of possible combinations of germination cues can accounts for many of the different responses observed in the same species…

- Order of cues
- Intensity of cues
- Duration of cues
- Number of cues

Plant Growth and Vigor

Most research has focused on germination but, in various species, smoke can:

- Promote seedling growth and vigor
- Significantly increase root length and frequency (in response to smoke water)
- Increases number of leaves
- Increase root and shoot weight



Smoke is more frequent than fire.

SOOoooo…species adapted to frequent fire, or that live in smokesheds with frequent fire, should have adaptations to smoke.

Questions:

By itself (without the heat of a fire) does smoke from ponderosa pine litter:

1) Affect the rate of sprouting of native species adapted to frequent fire?
2) Affect the timing of sprouting of native species adapted to frequent fire?
3) Affect the sprouting of native species if only the soil, and not the seeds, are exposed to smoke?

Methodology

2014

Four treatments

A: Control

B: Only soil smoked

C: Only seed smoked

D: Soil & Seed smoked

2015

Six treatments

A: Control

B: Only soil smoked

C: Only seed smoked

D: Soil & Seed smoked

E: Only seed, 1 week lag

F: Soil & Seed, 1 week lag

Methodology

2014

Eight species – five with usable data

Thermopsis pinetorum

Penstemon virgatus

Linum lewisii

Ipomopsis aggregata

Penstemon grandiflorus

~~*Symphotrichum falcatum var.*~~

~~*Eriogonum umbellatum*~~

~~*Eriogonum racemosum*~~

2015

Four species with two ecotypes of one

Thermopsis pinetorum

Penstemon virgatus

Linum lewisii

Penstemon barbatus **(collected in September 2014 near MP 18, Highway 83 near Elgin, Arizona)**

Penstemon barbatus **(collected October 2014 near Flagstaff, Arizona)**

Methodology

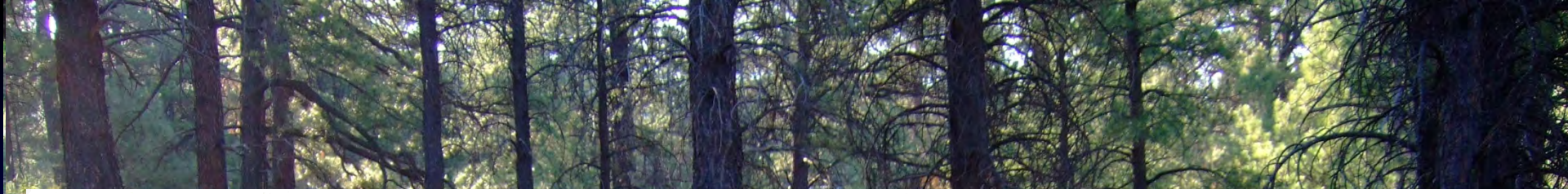
Potentially significant differences in methodology between 2014 & 2015 include:

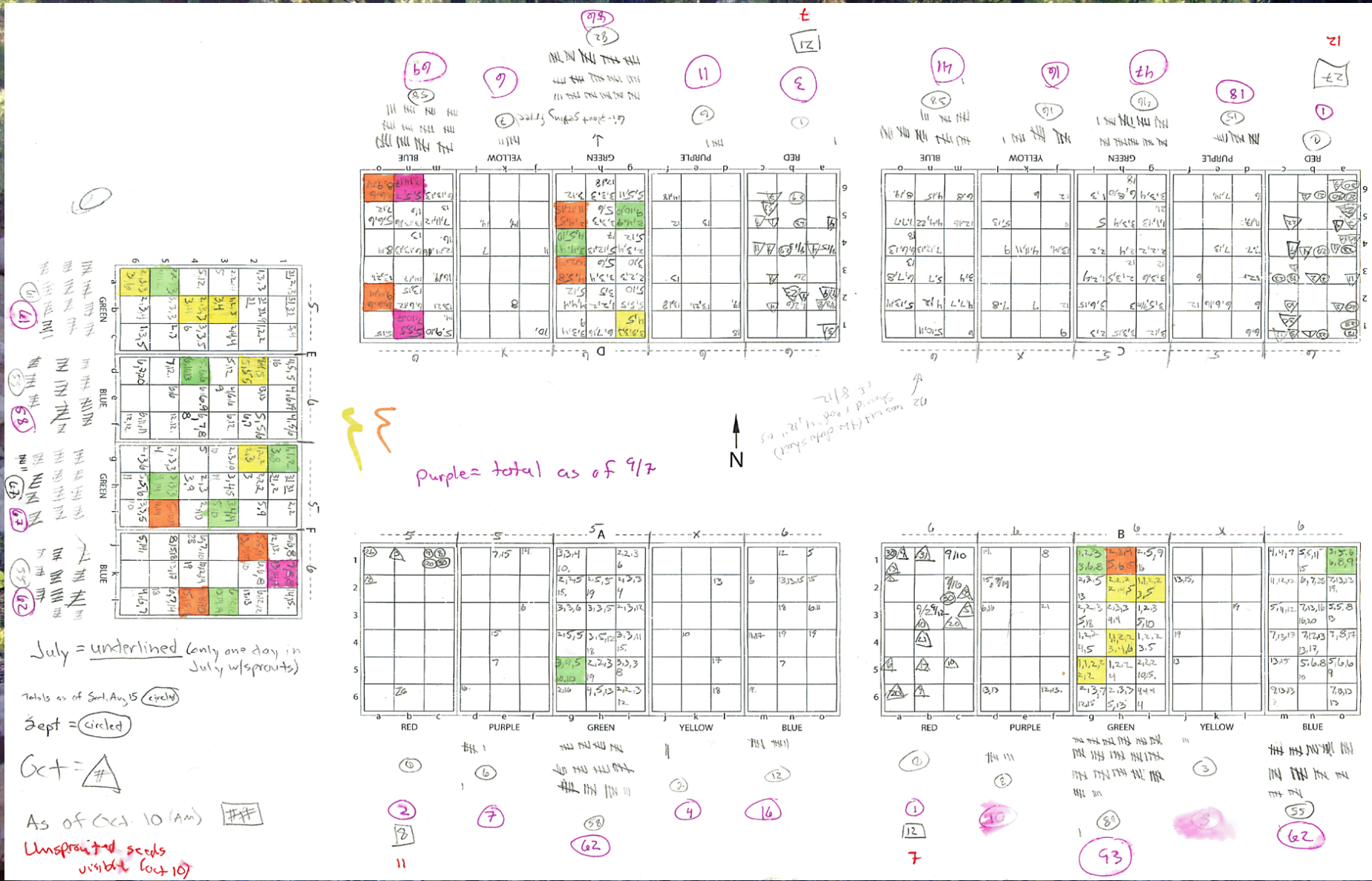
- Potting soil quality
- Duration of smoke exposure (seeds and soil)
- Seed stratification
- Weather (cooler and higher humidity in 2015)

2014

2015

A Control



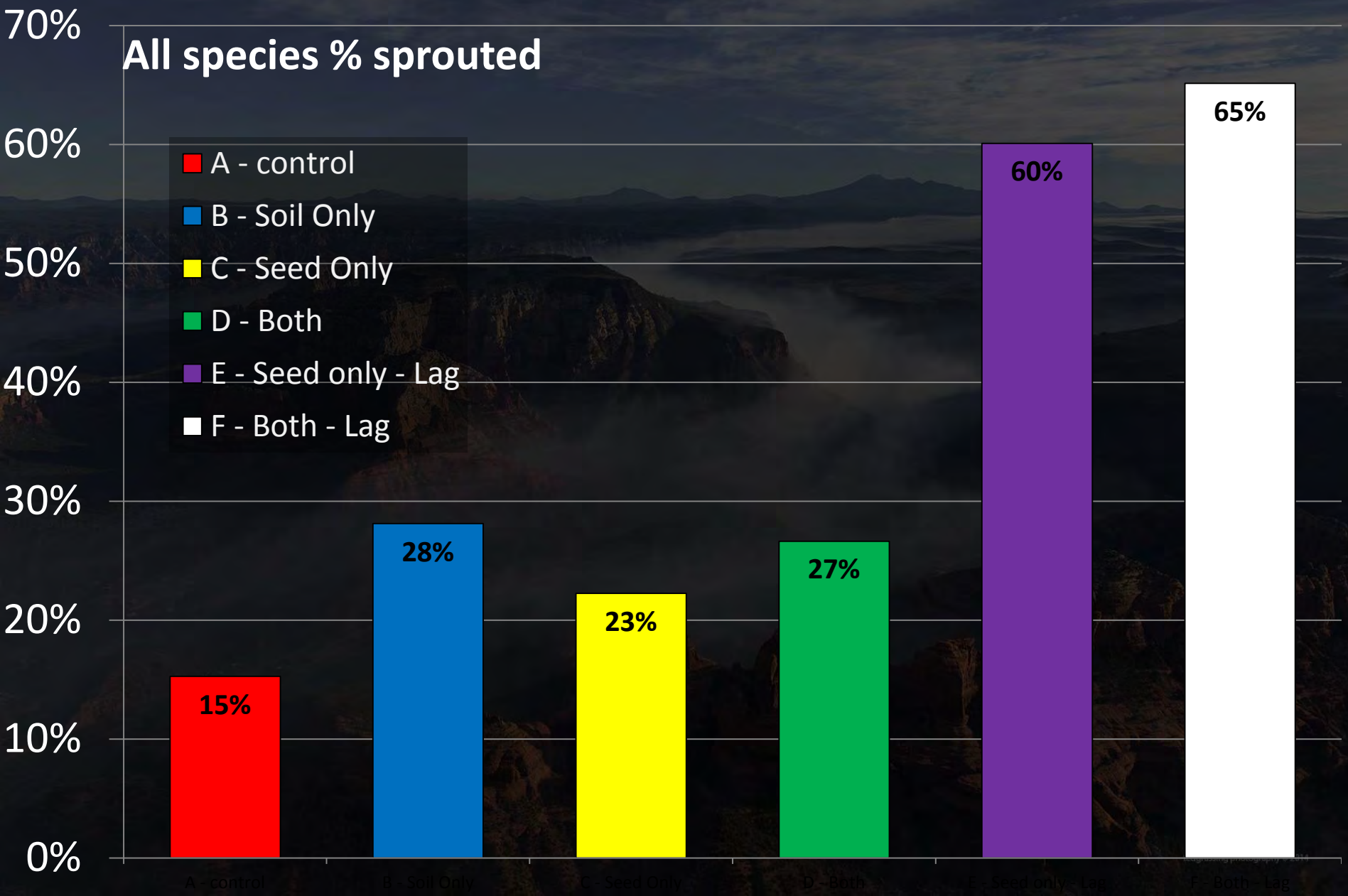

N
purple = total as of 9/7
July = underlined (only one day in July w/sprouts)
Totals as of Sat. Aug 15 (circle)
Sept = circled
Oct = #
As of Oct. 10 (Am) ##
Unsprouted seeds visible (Oct 10)
RED
PURPLE
GREEN
YELLOW
BLUE

Results: Sprouting rates – all sprouts

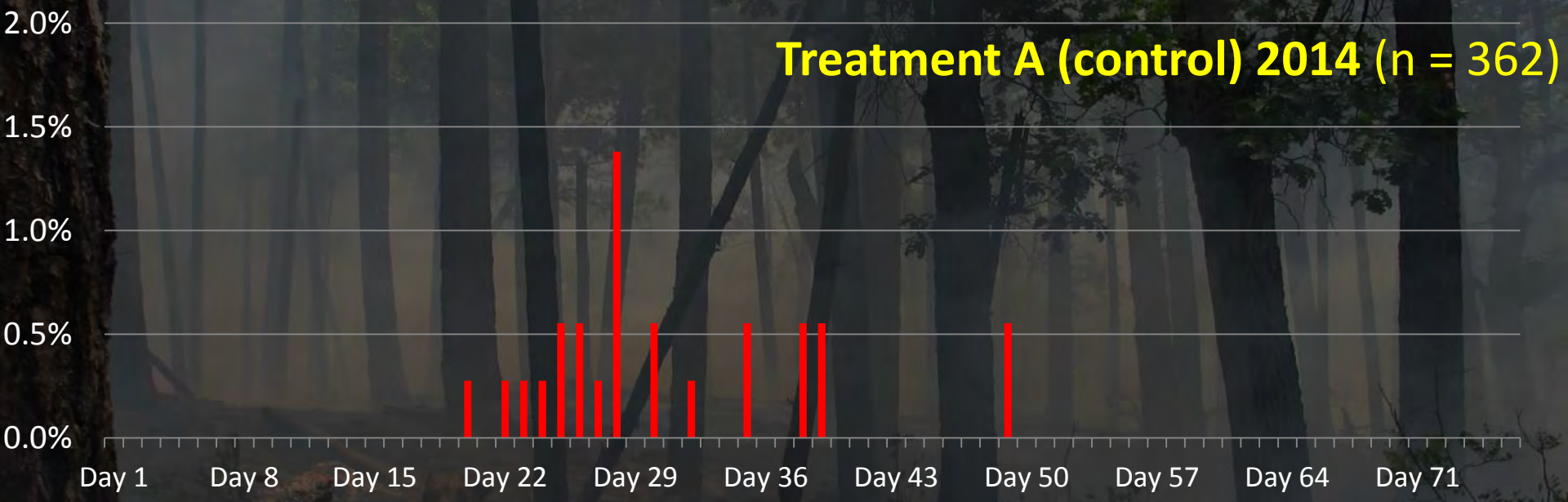
2014		
	# of sprouts	% sprouted
A: Control	25	7%
B: Soil Only	42	12%
C: Seed Only	32	8%
D: Both	35	9%

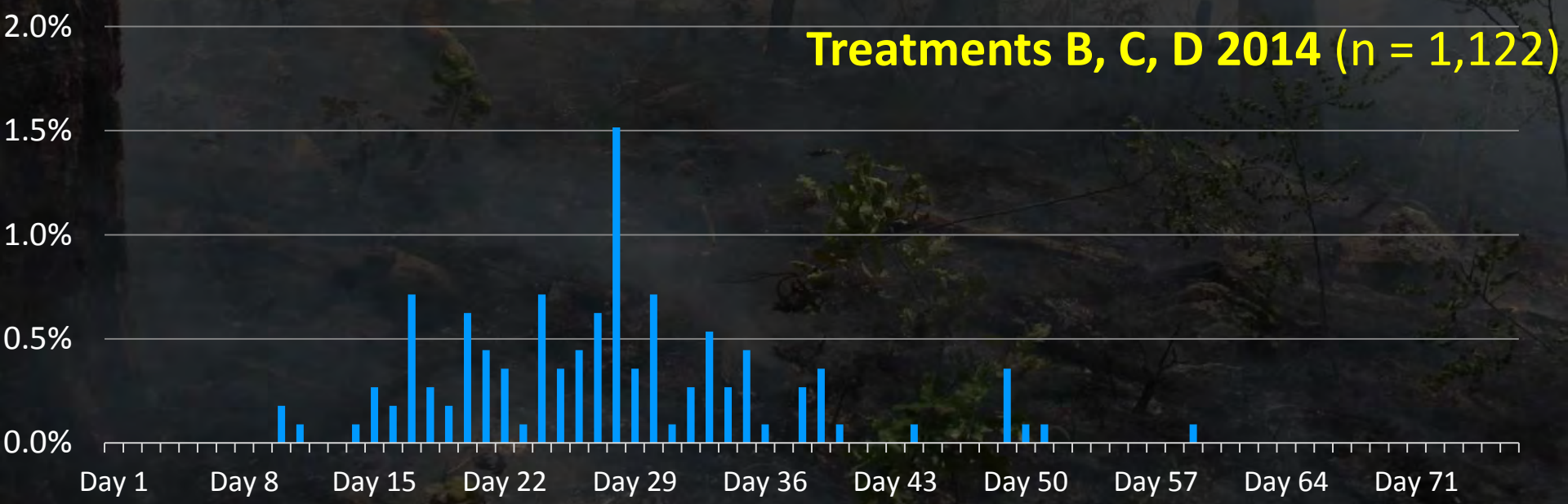
2015		
	# of sprouts	% sprouted
A: Control	97	22%
B: Soil Only	190	40%
C: Seed Only	154	34%
D: Both	194	43%
E: Seed only, Lag	119	60%
F: Both, Lag	129	65%

Results: Sprouting rates – all species

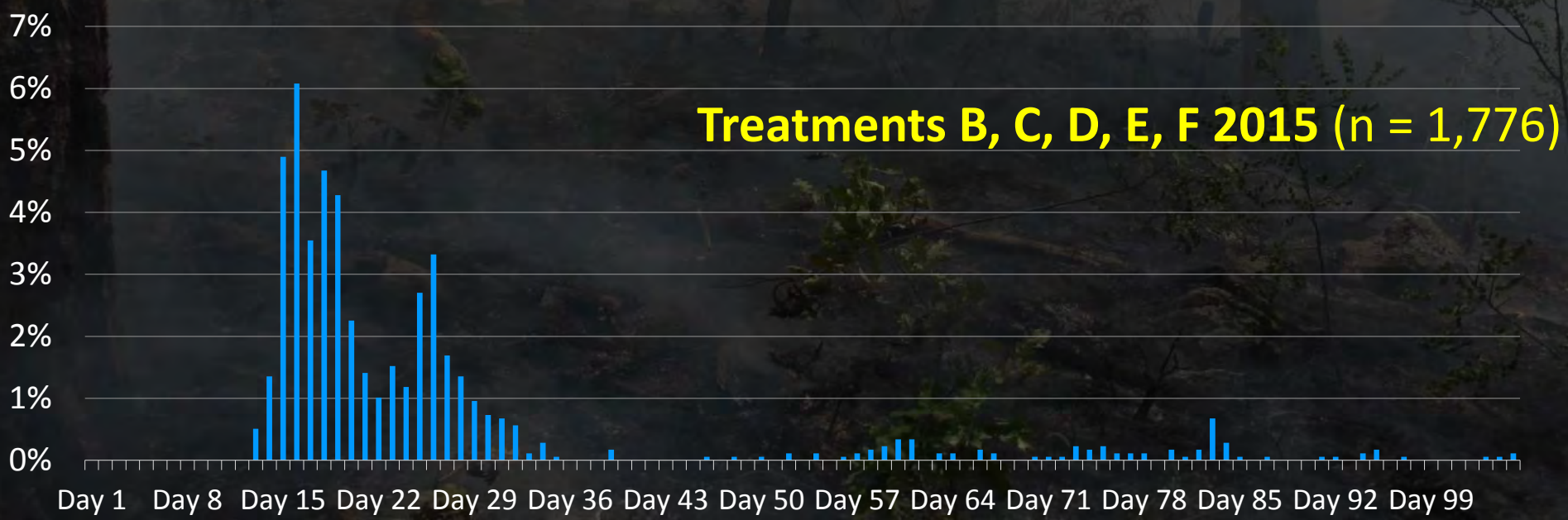


Results: Timing - 2014

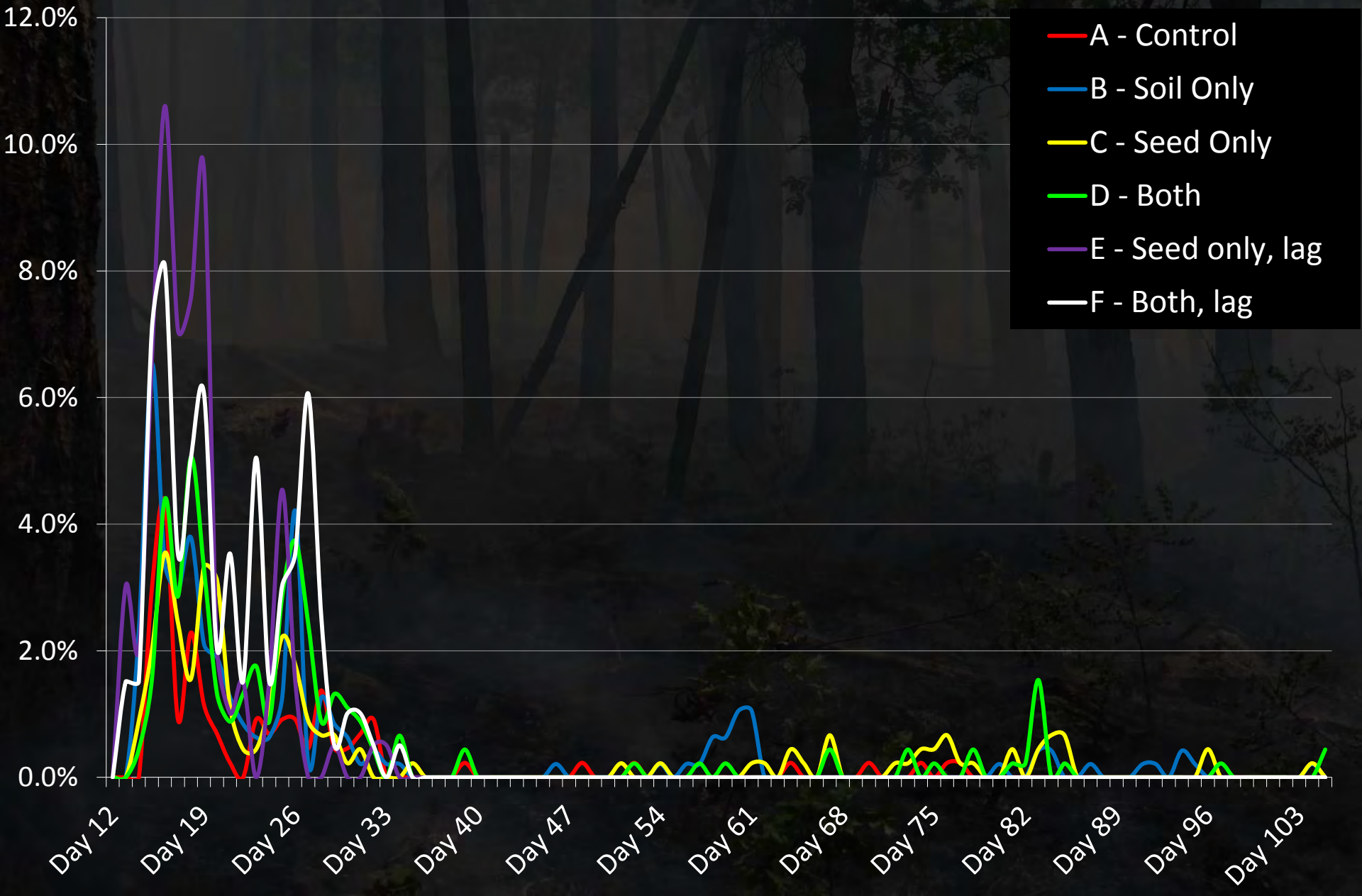




Results: Timing - 2015



Results: Timing - All sprouts 2015



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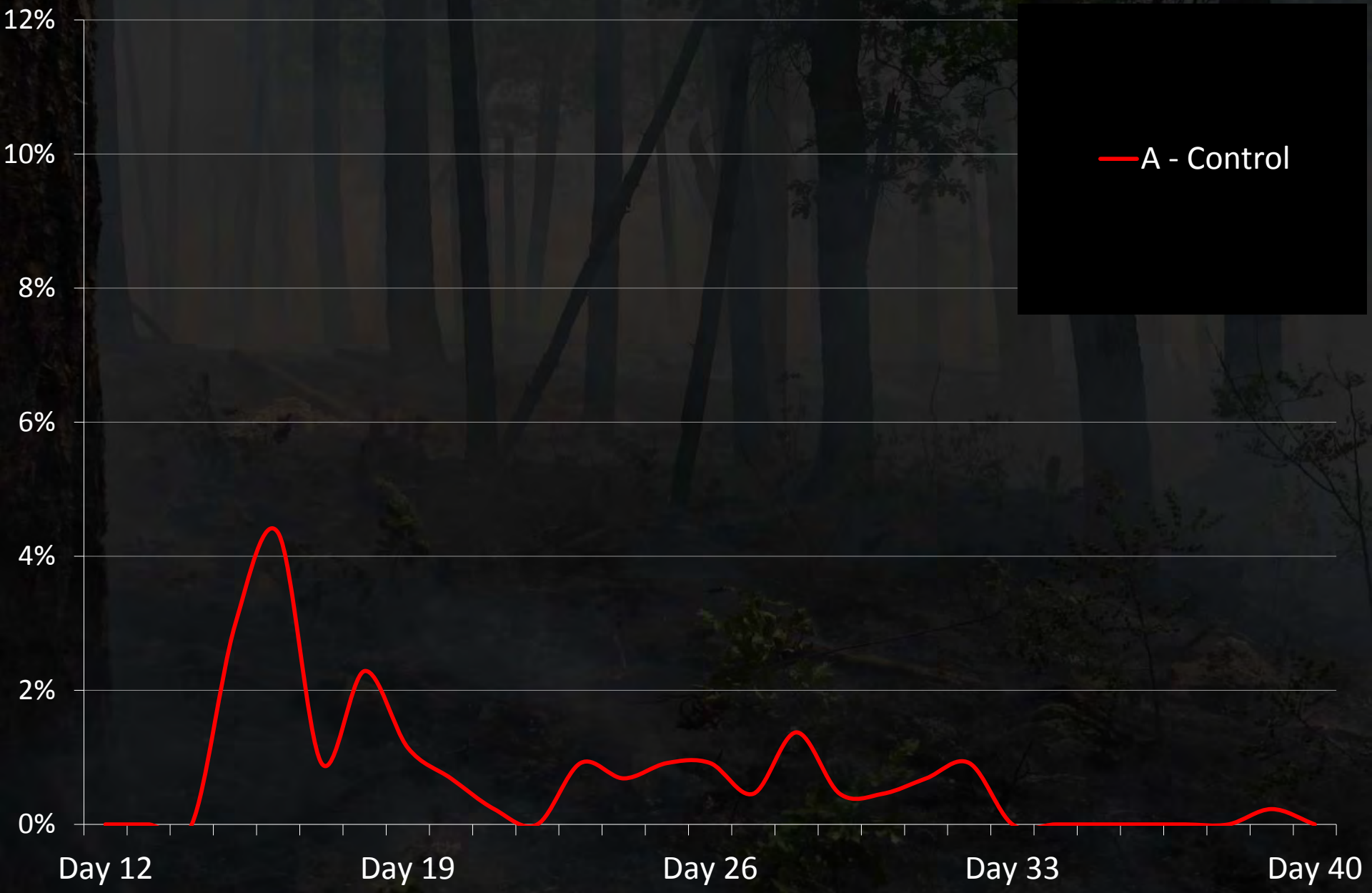

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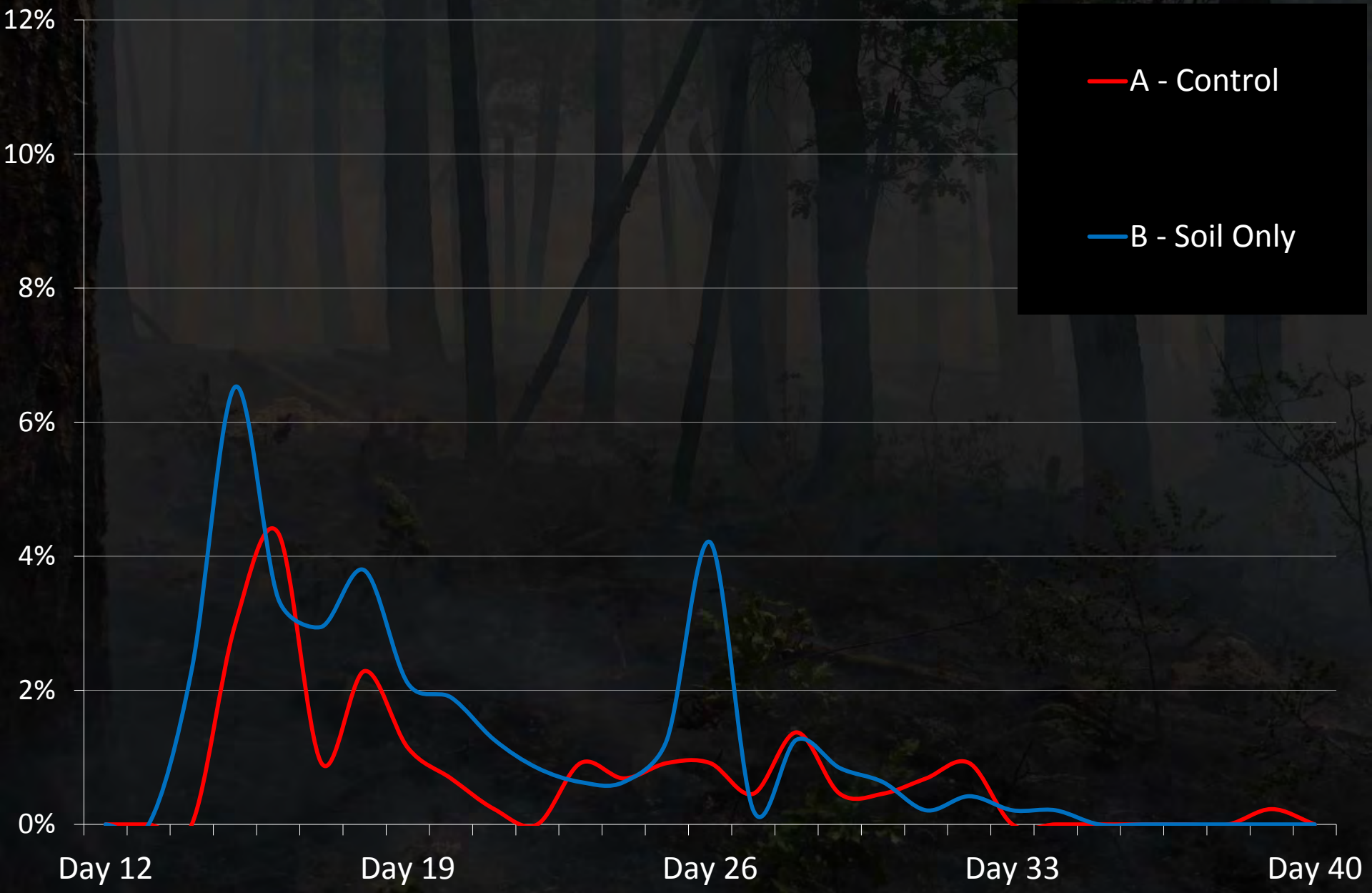

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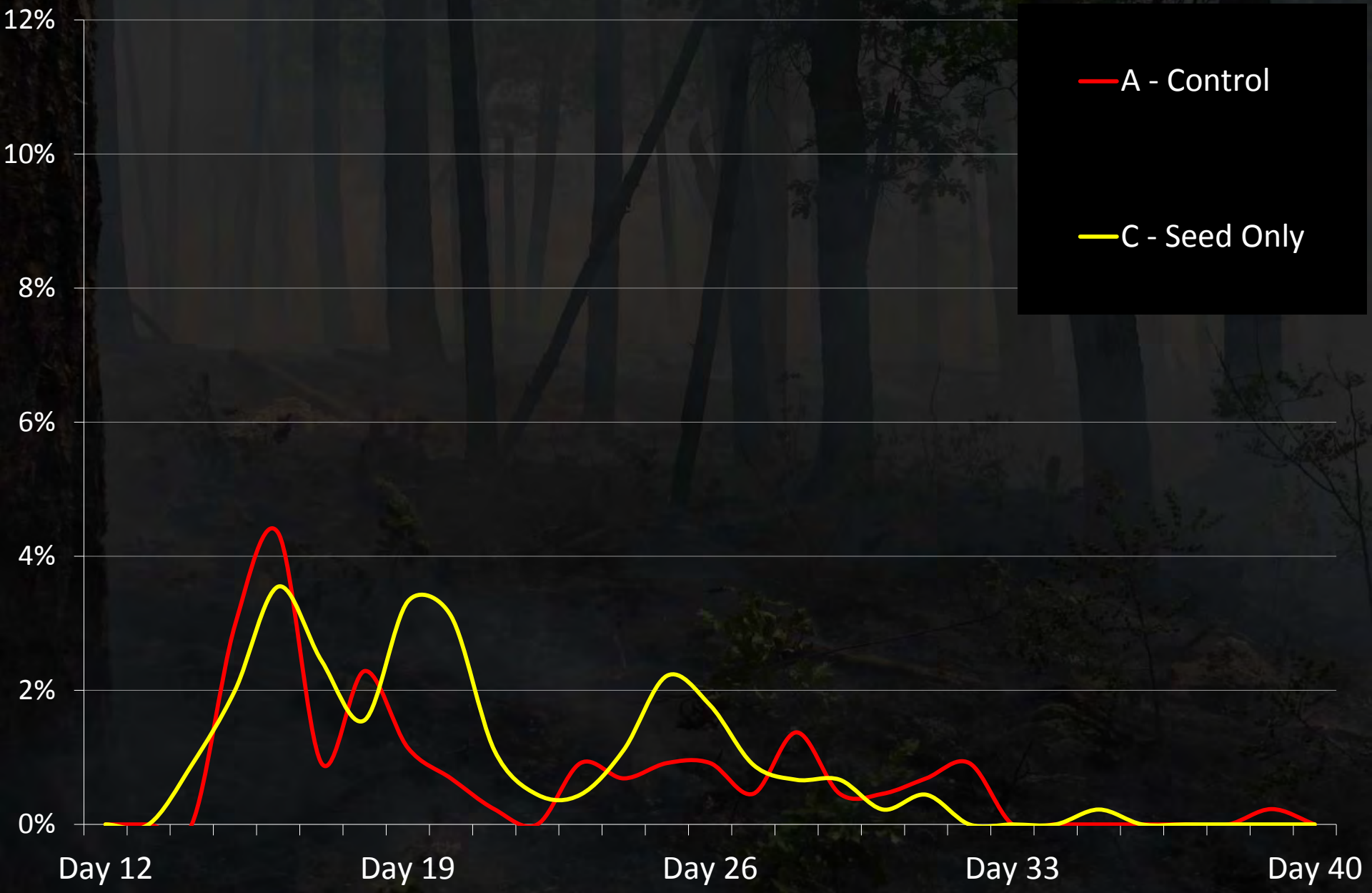

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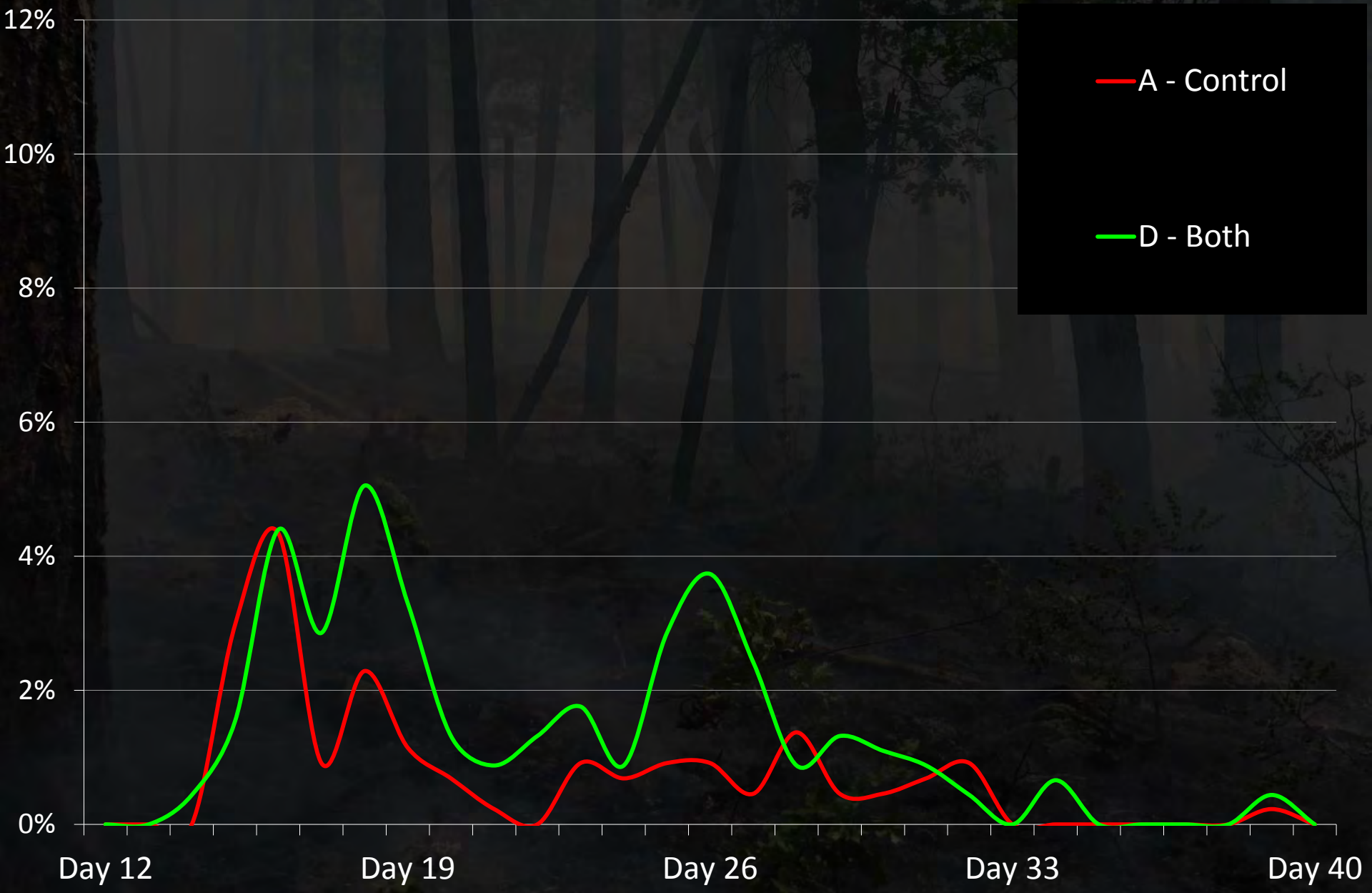

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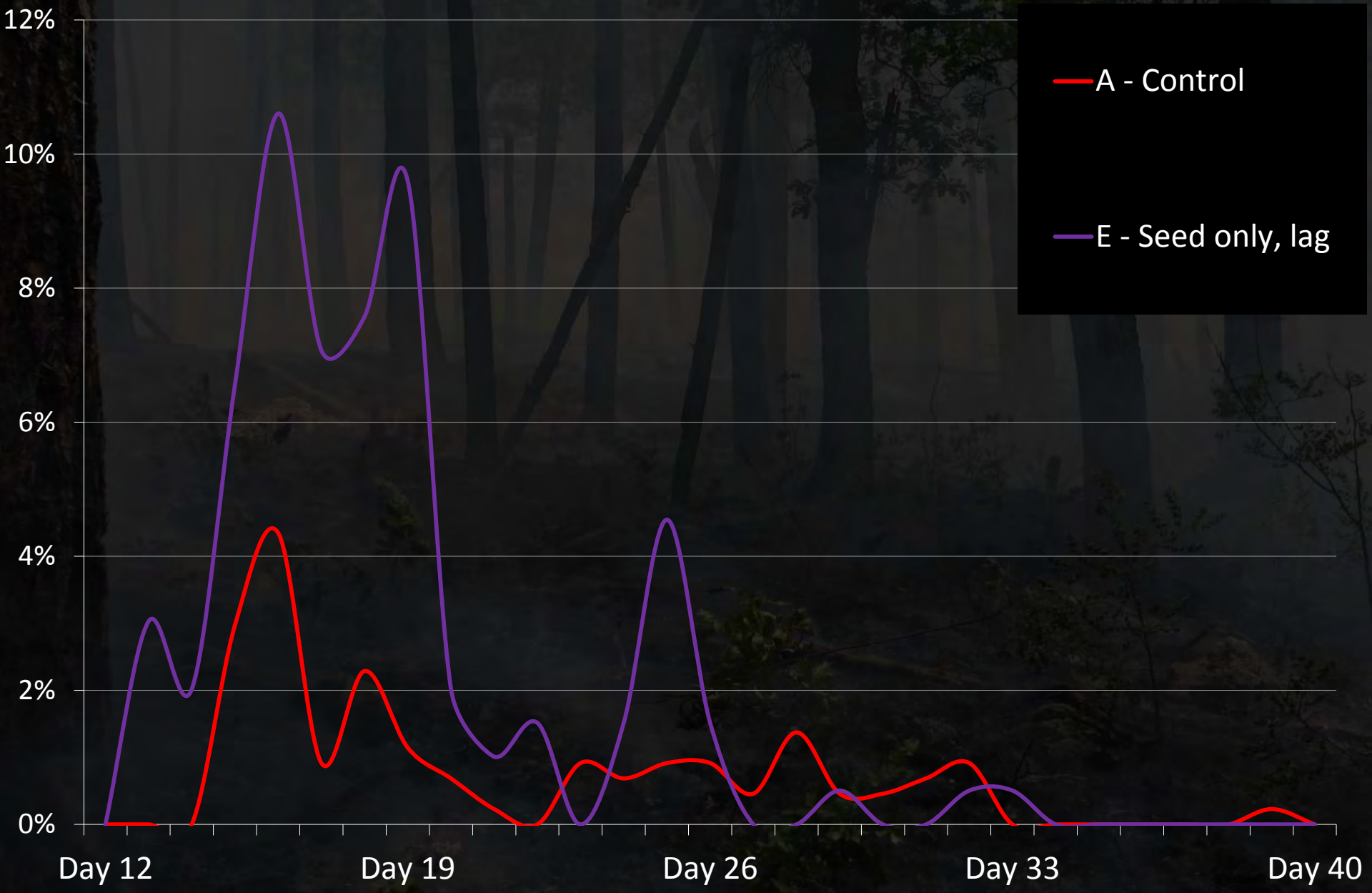

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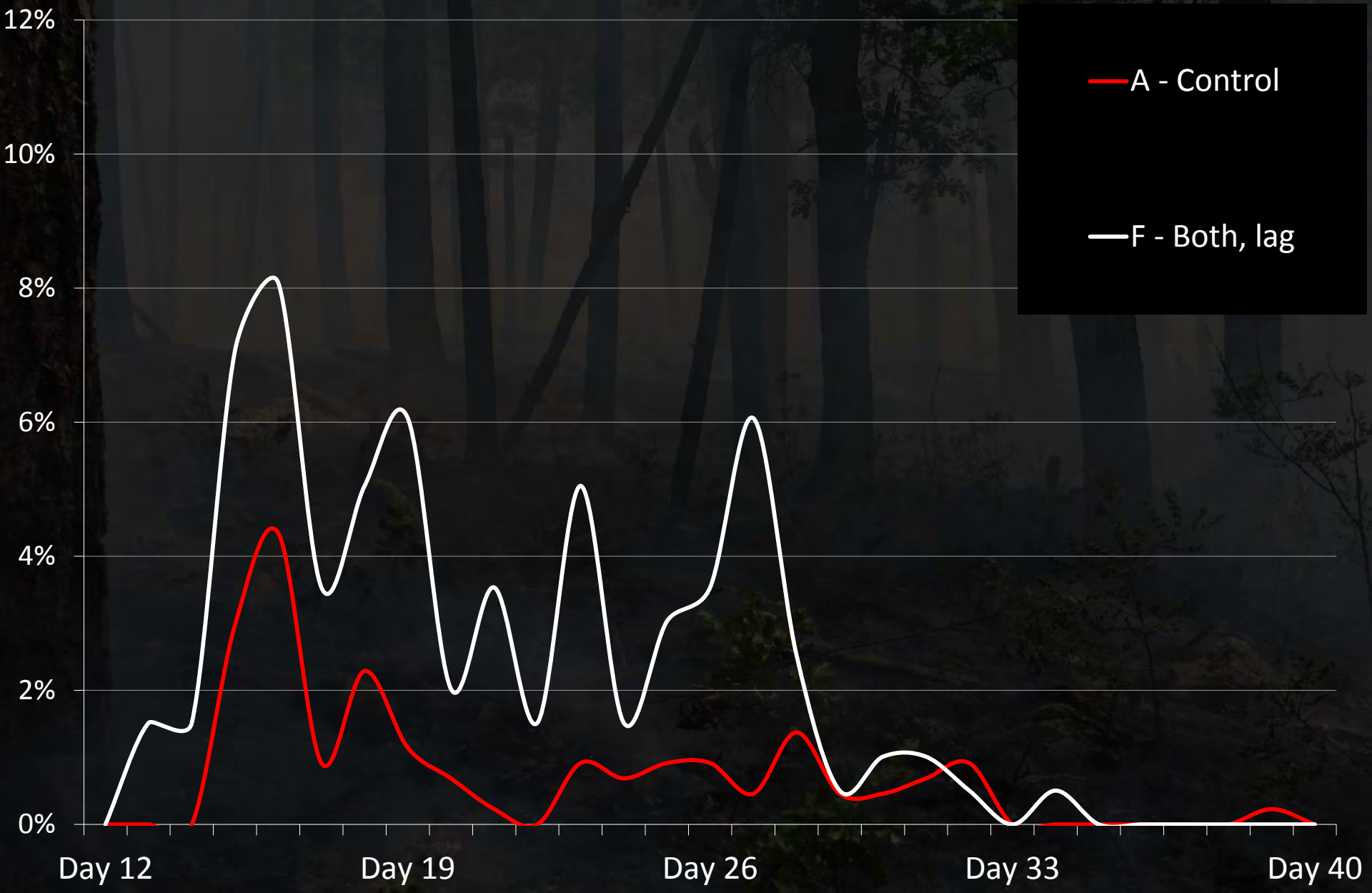

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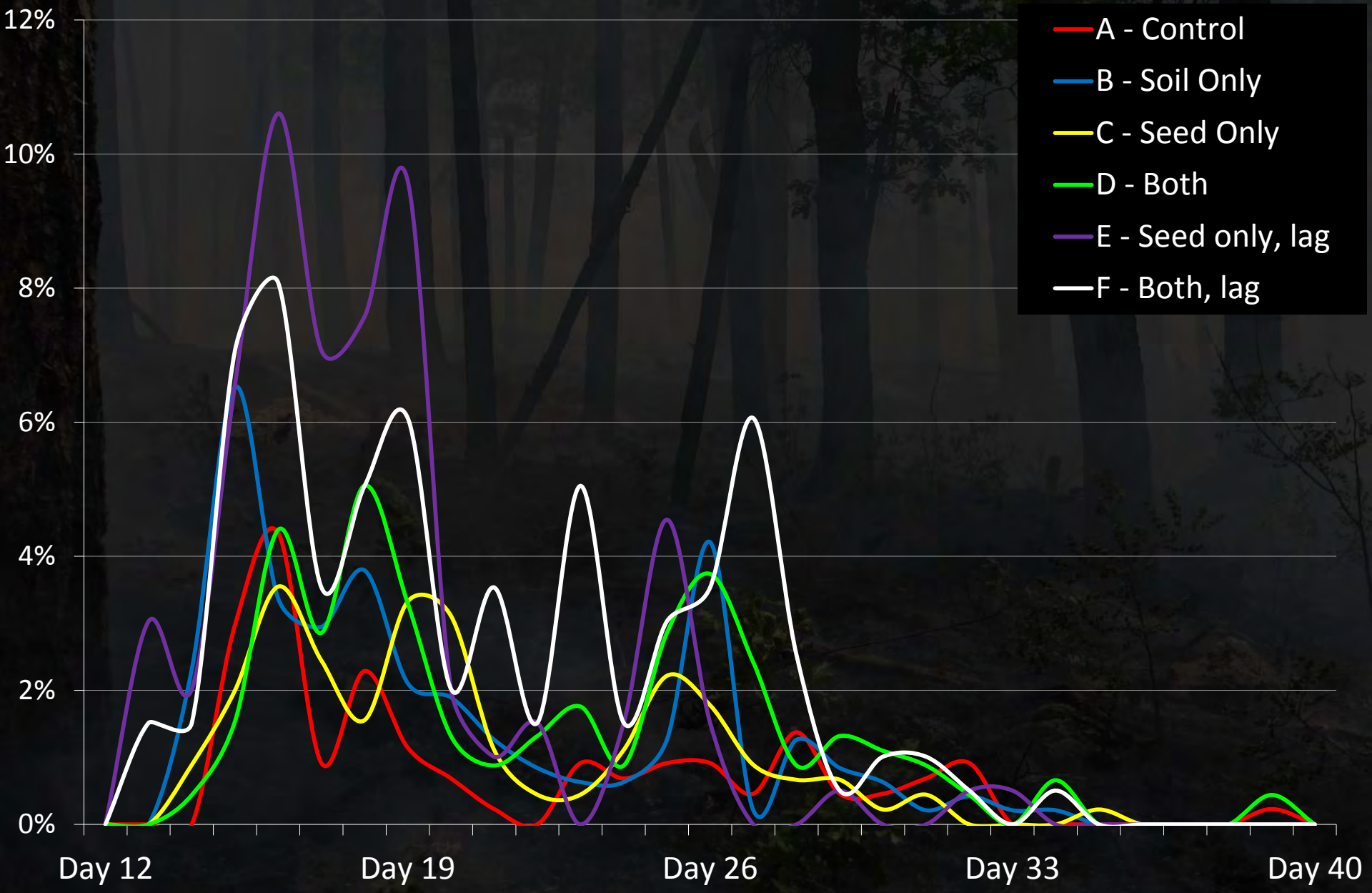
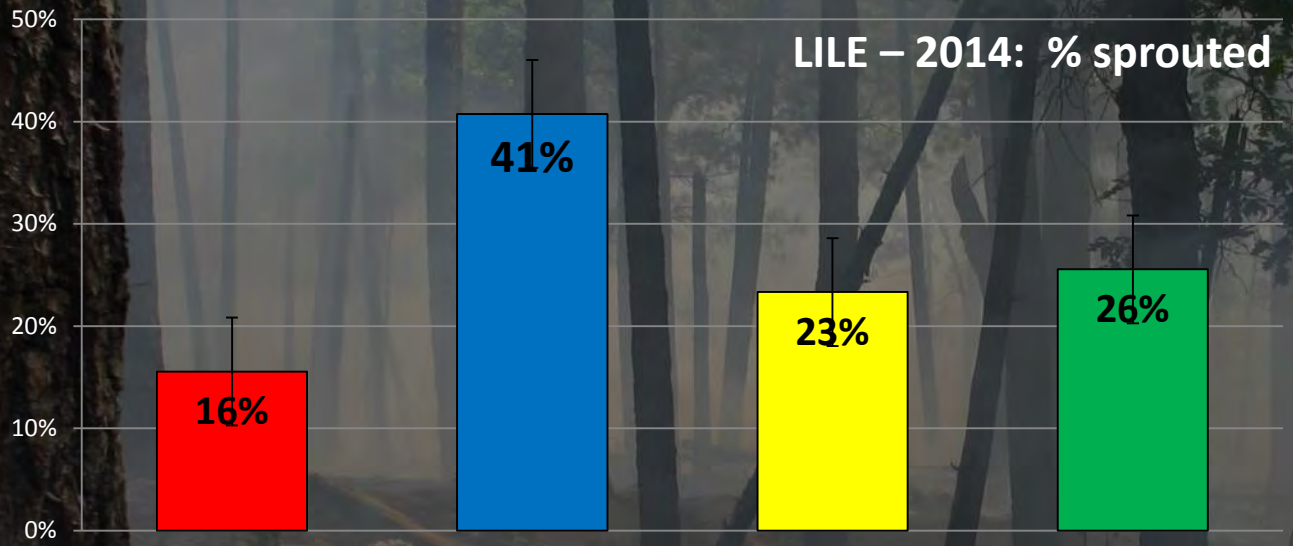
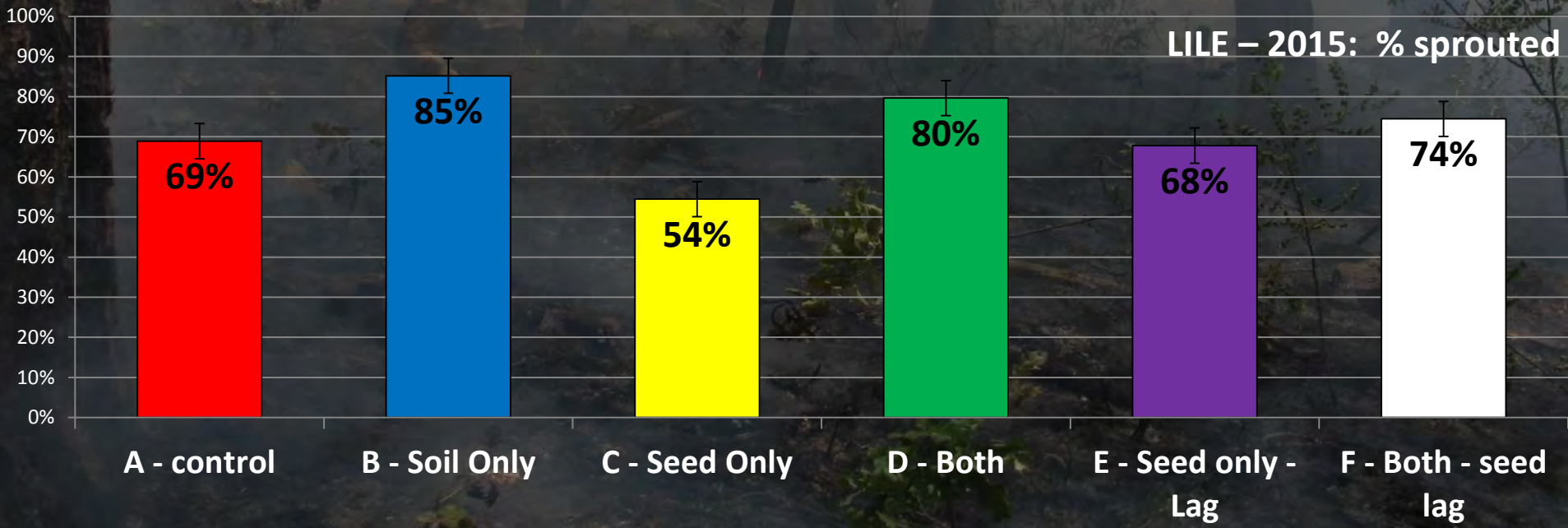
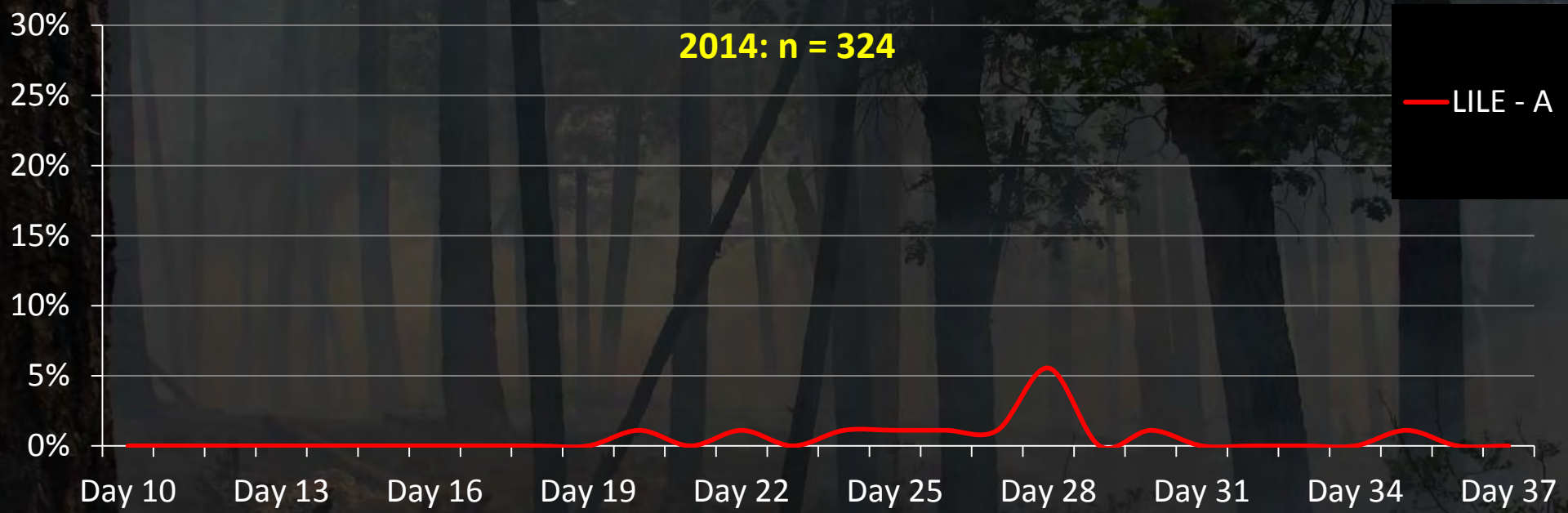


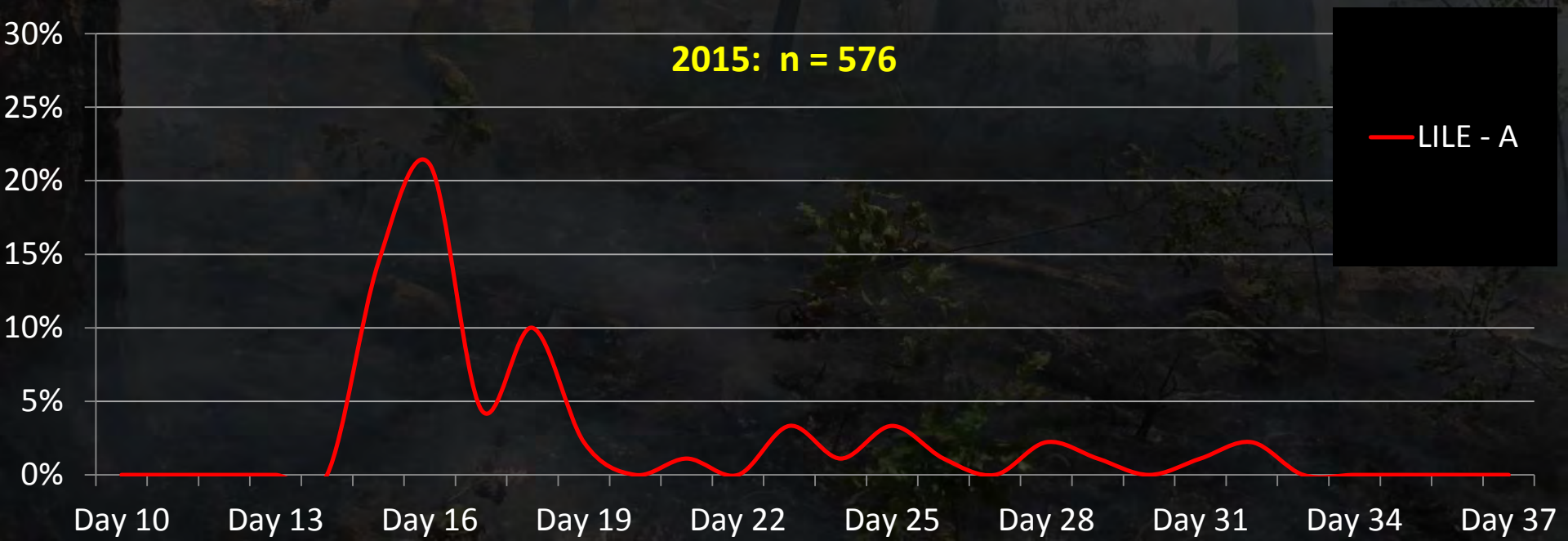
Results: Rate of sprouting – *Linum lewisii*





Results: Timing – *Linum lewisii*





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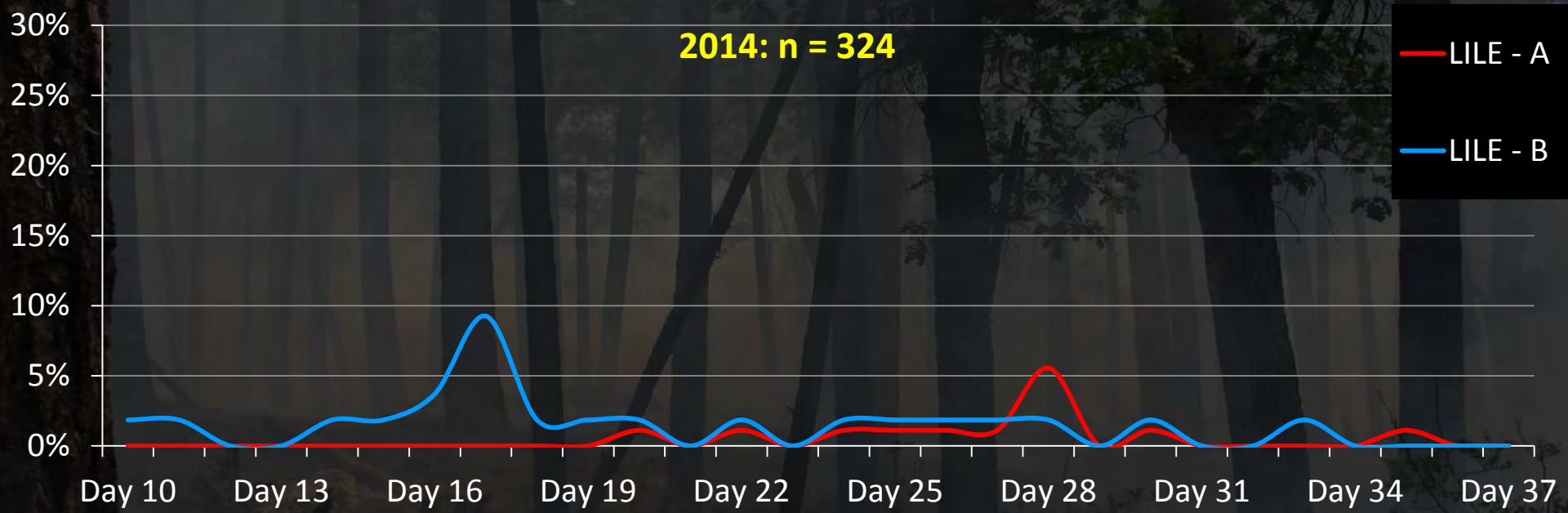

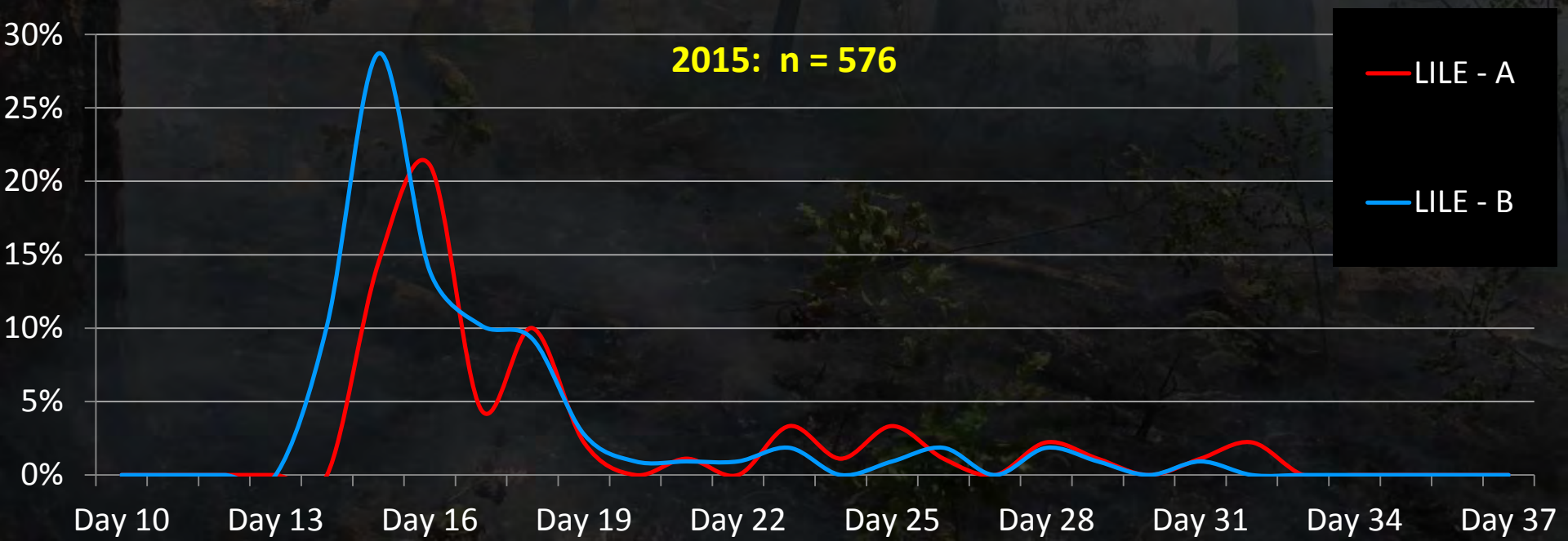

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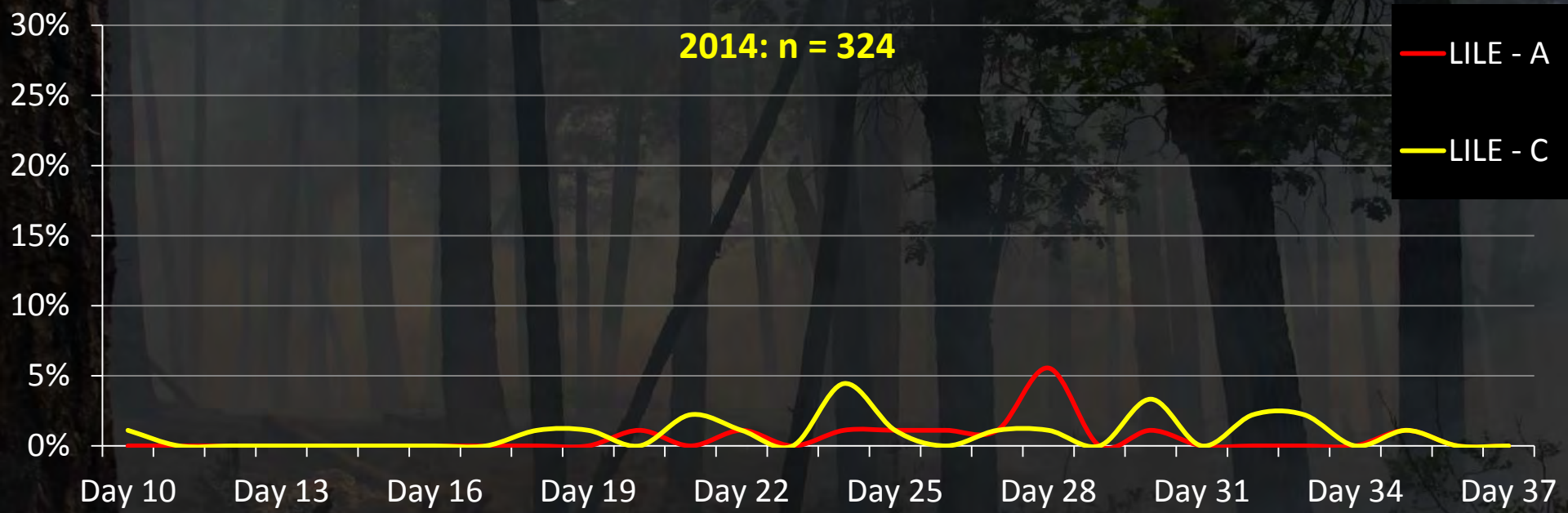

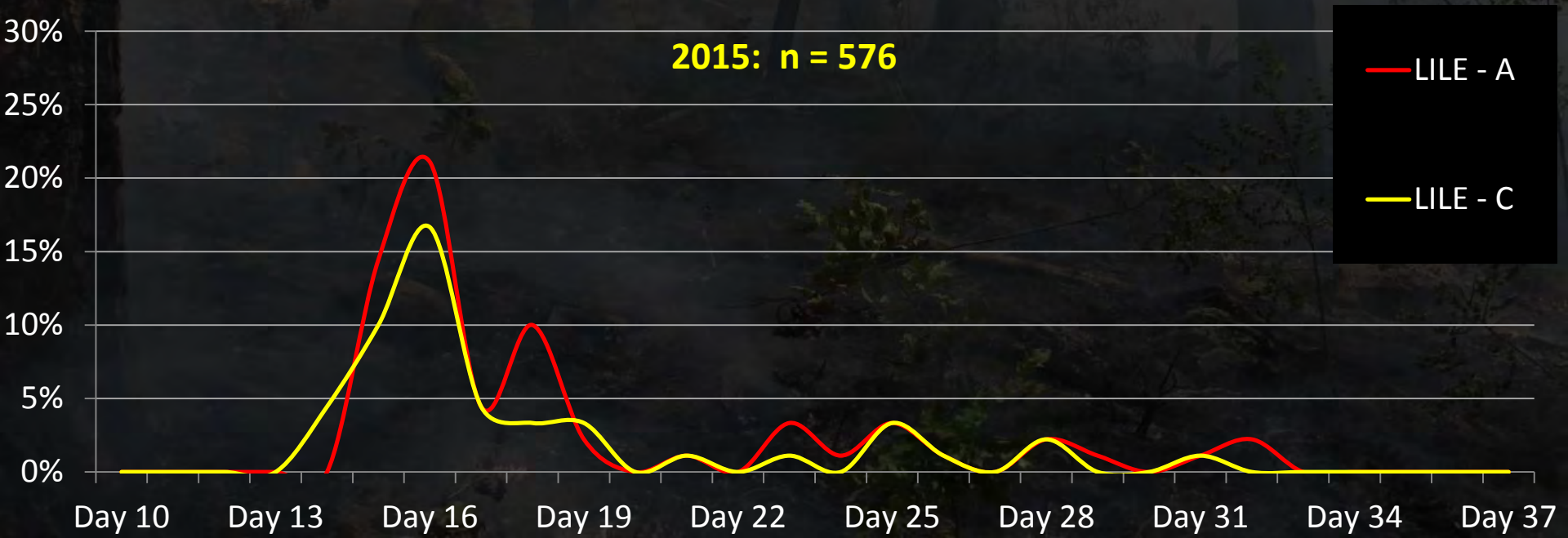

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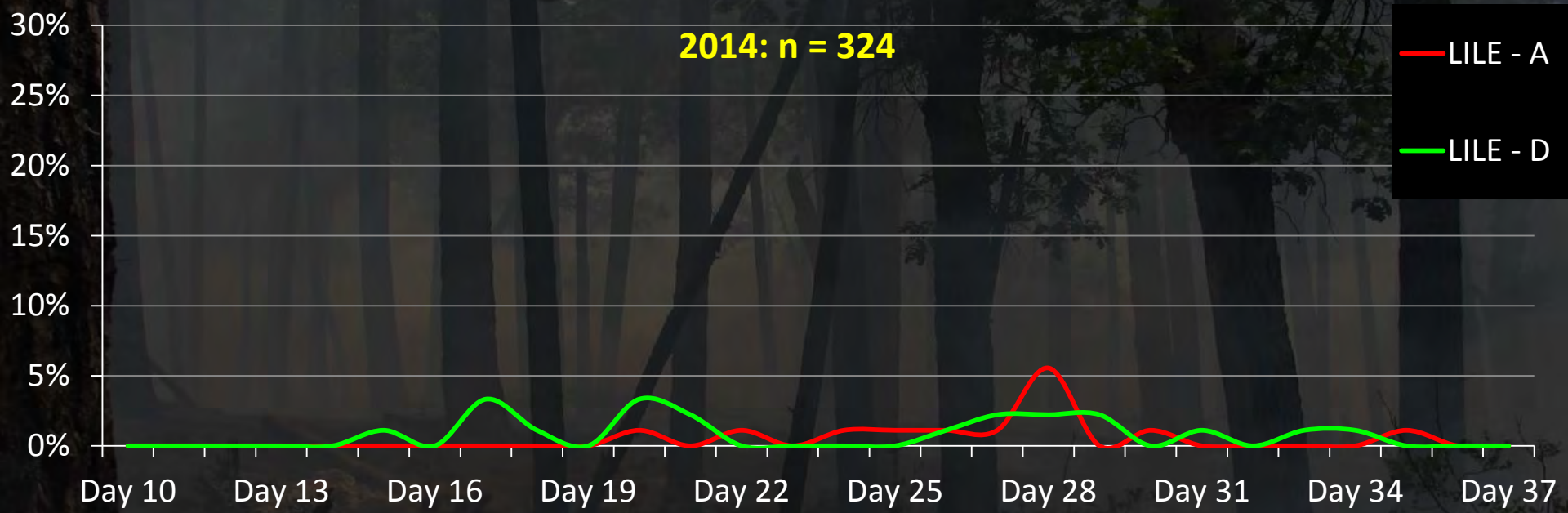

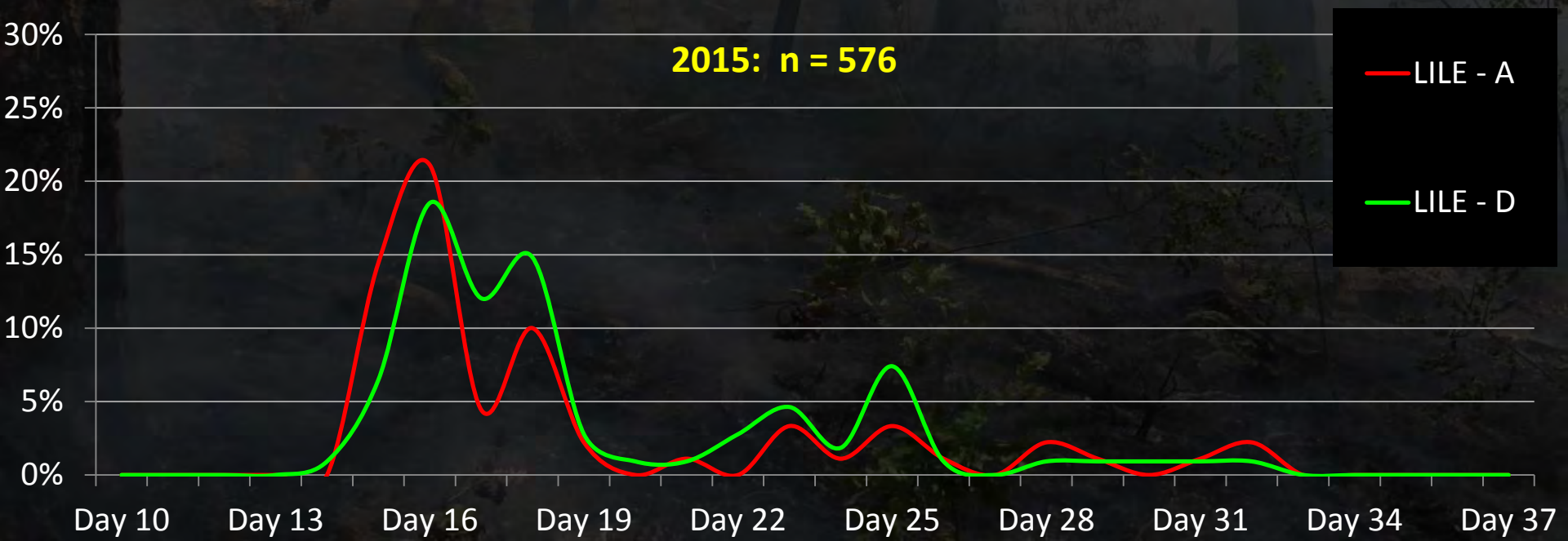

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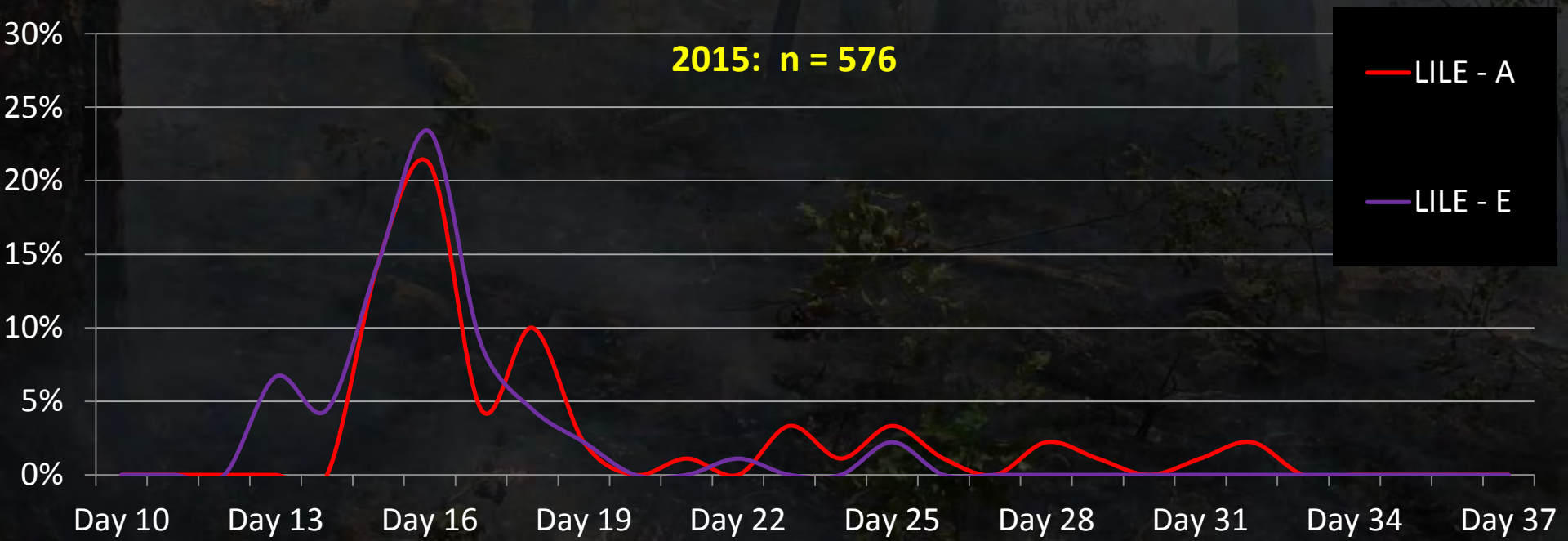

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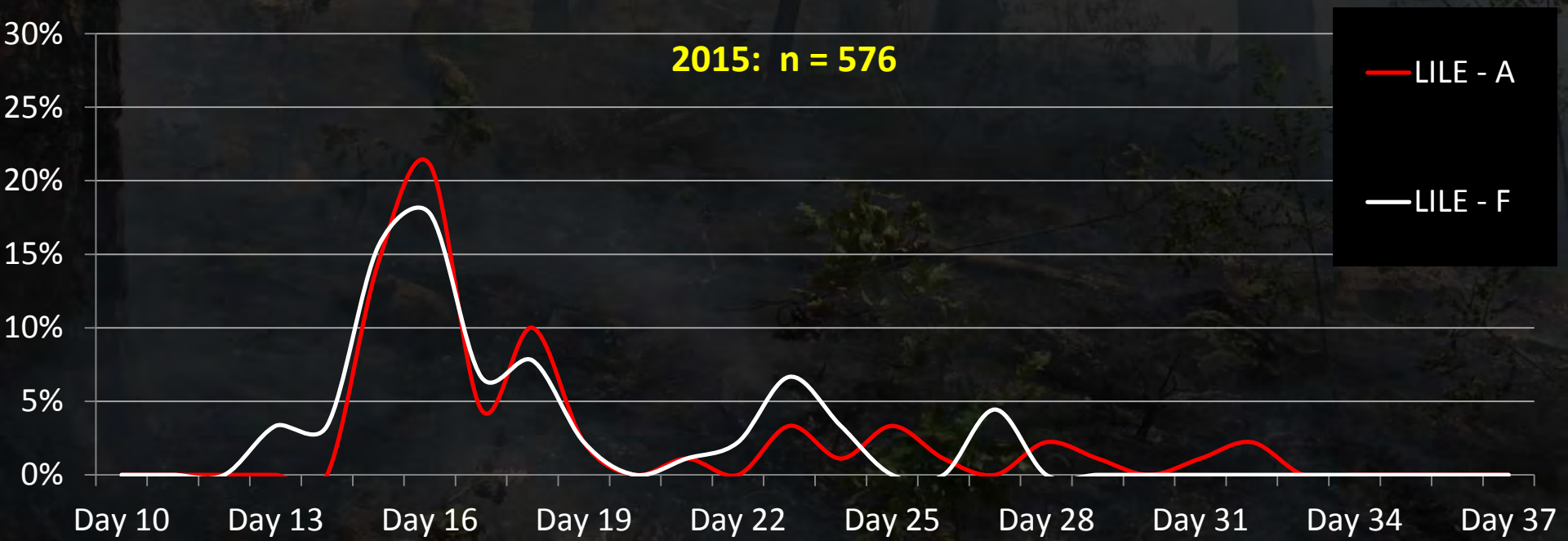

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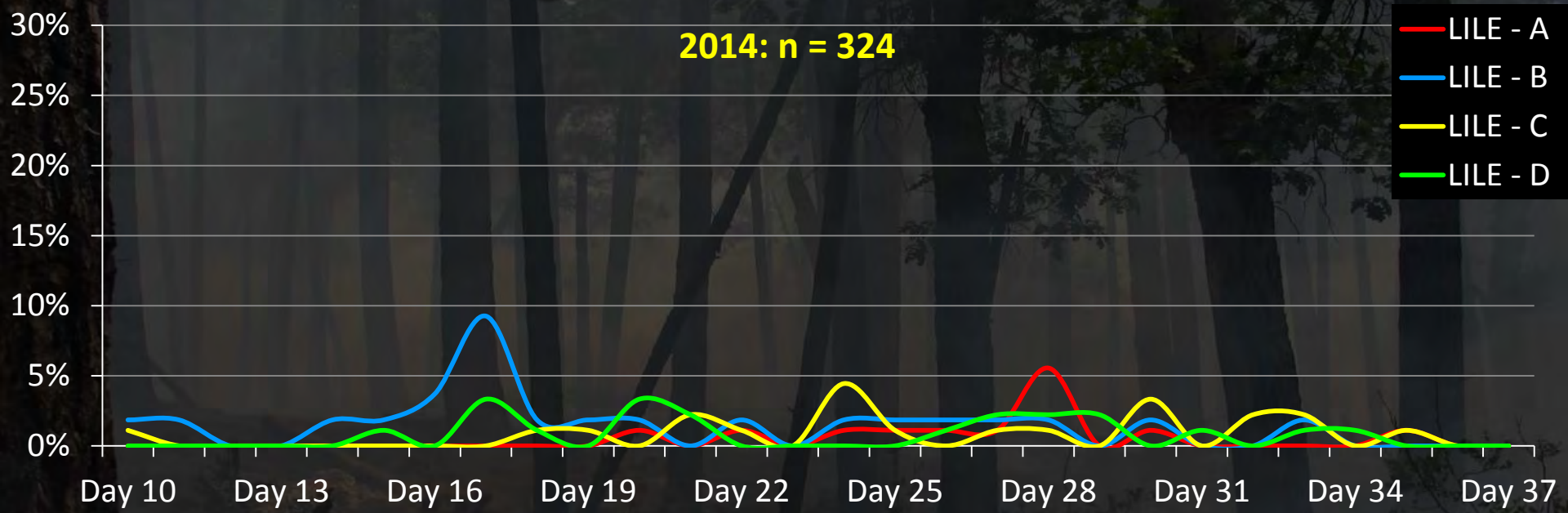
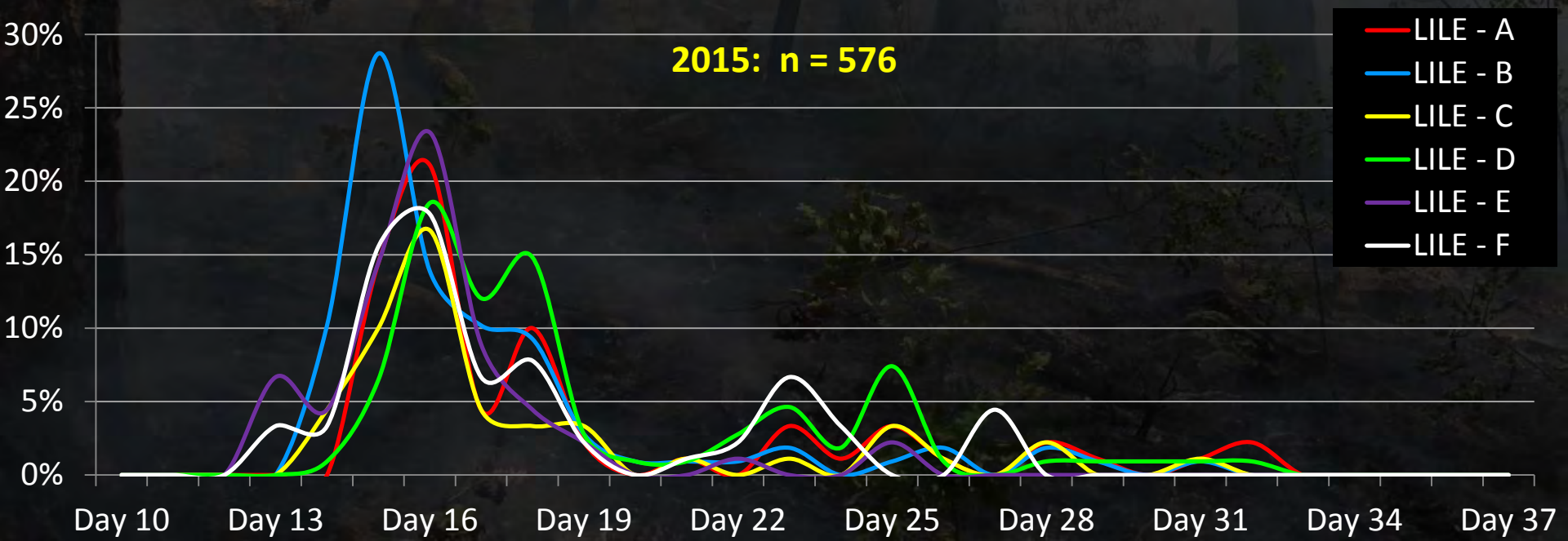




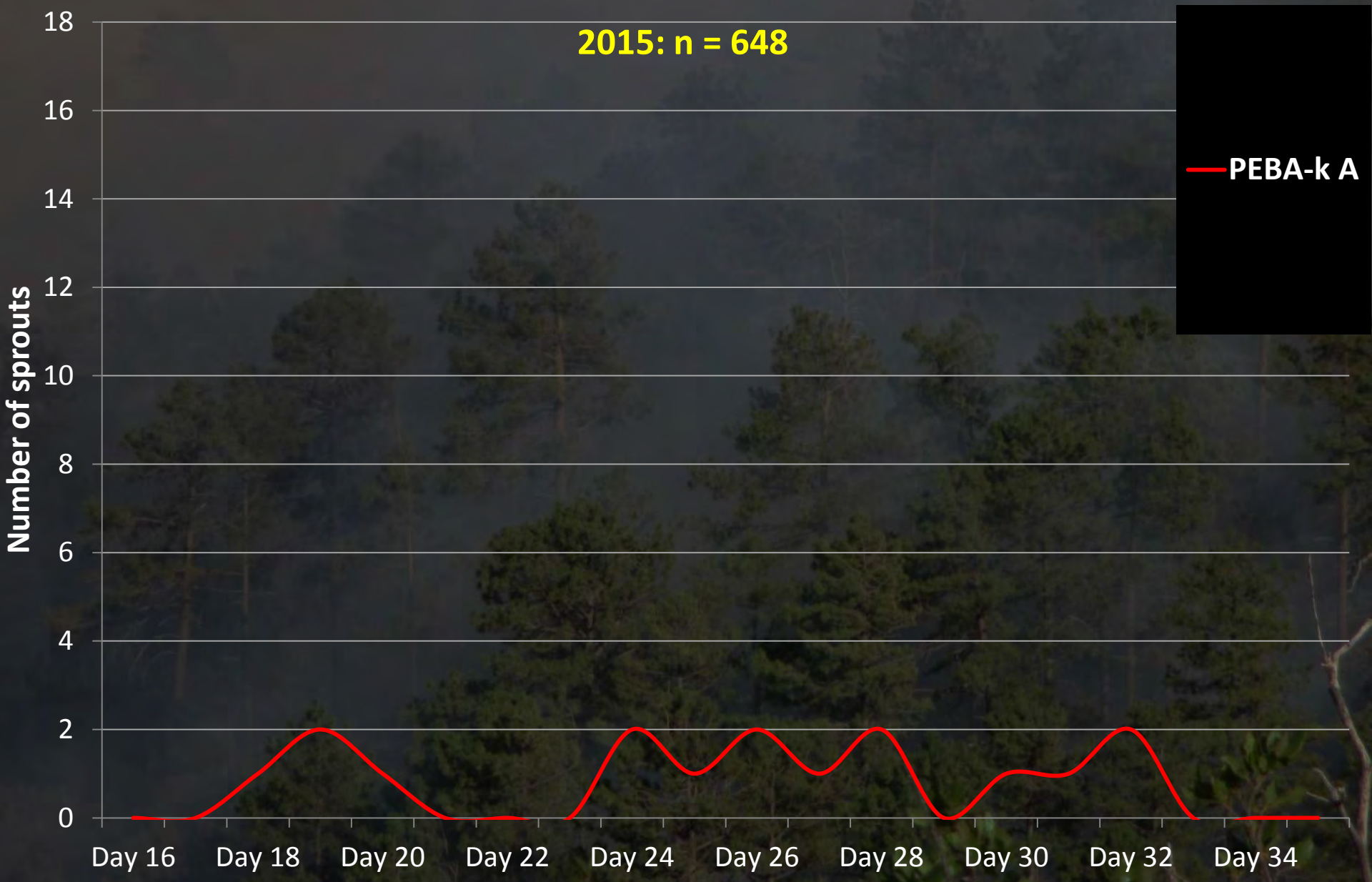
Results: Sprouting rates – LILE (Blue Flax)

Linum lewisii		
	# sprouts	% sprouted
A: Control	76	42%
B: Soil Only	114	70%
C: Seed Only	70	39%
D: Both	109	55%
E: Seed only, Lag	61	68%
F: Both, Lag	67	74%

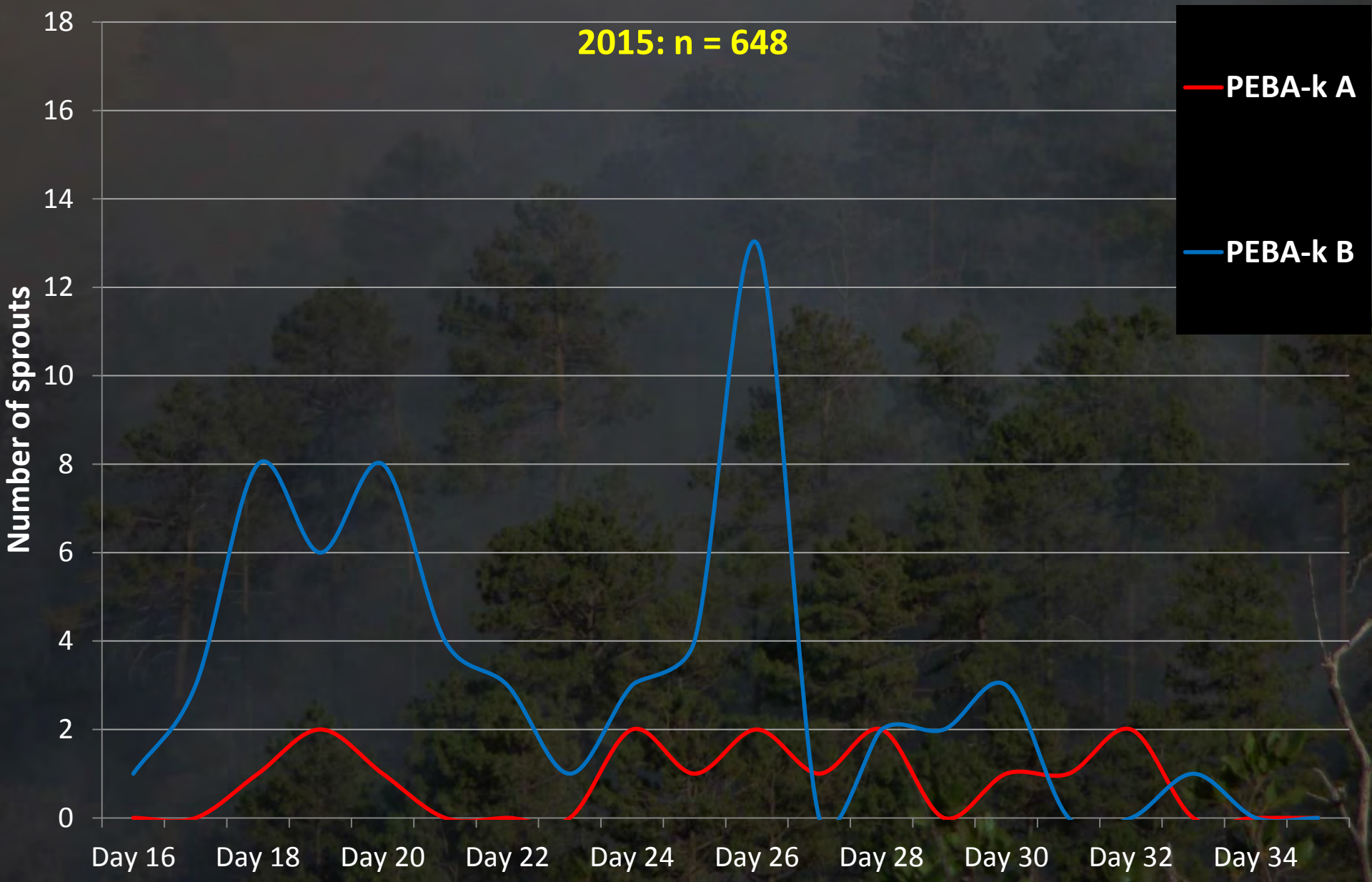
Results: Sprouting rates – PEBA

Penstemon barbatus		
	# sprouts	% sprouted
A: Control	16	15%
B: Soil Only	64	59%
C: Seed Only	41	38%
D: Both	69	64%
E: Seed only, Lag	58	54%
F: Both, Lag	62	57%

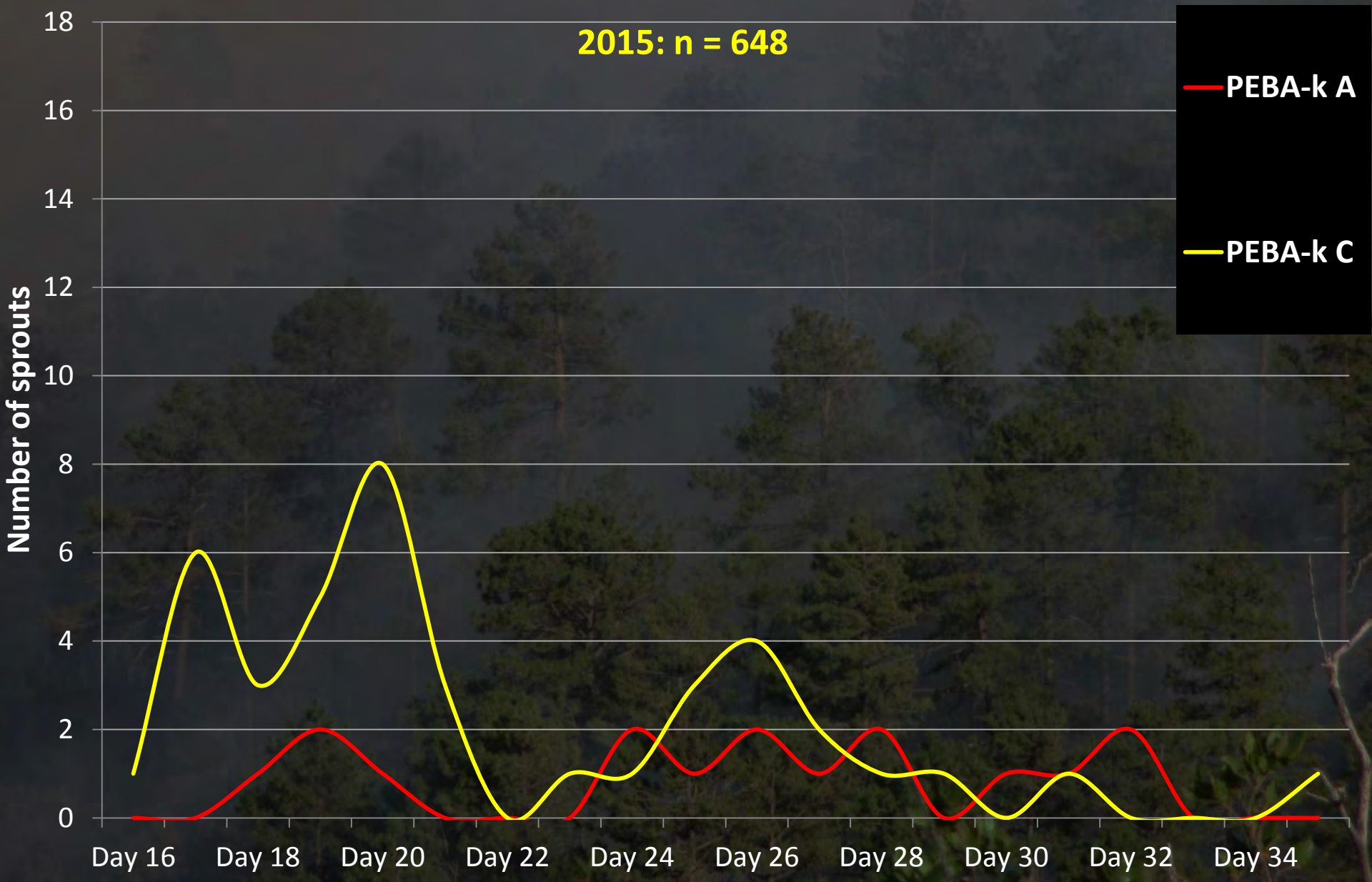
Results: Timing – *Penstemon barbatus*



Results: Timing – *Penstemon barbatus*



Results: Timing – *Penstemon barbatus*



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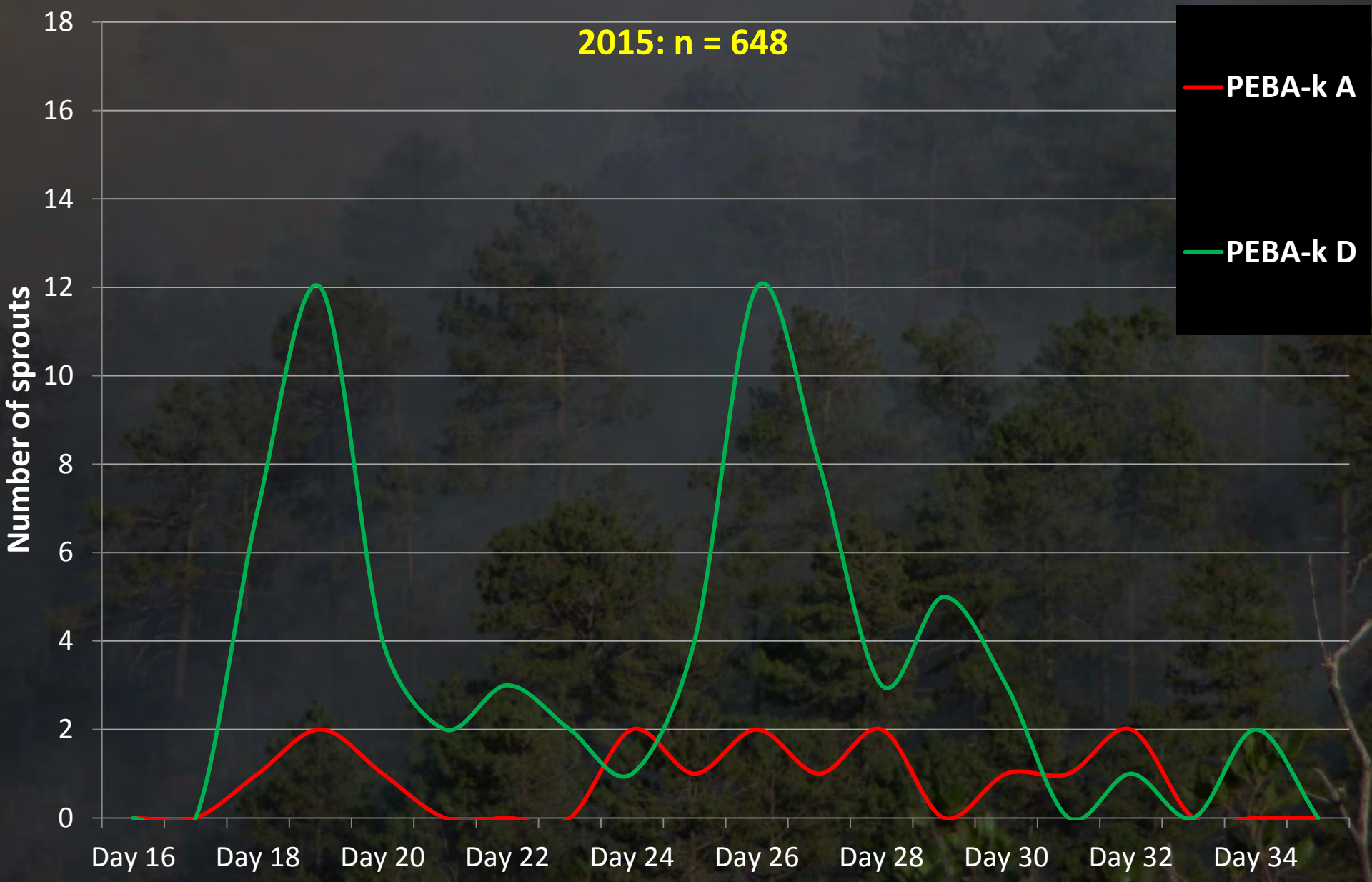

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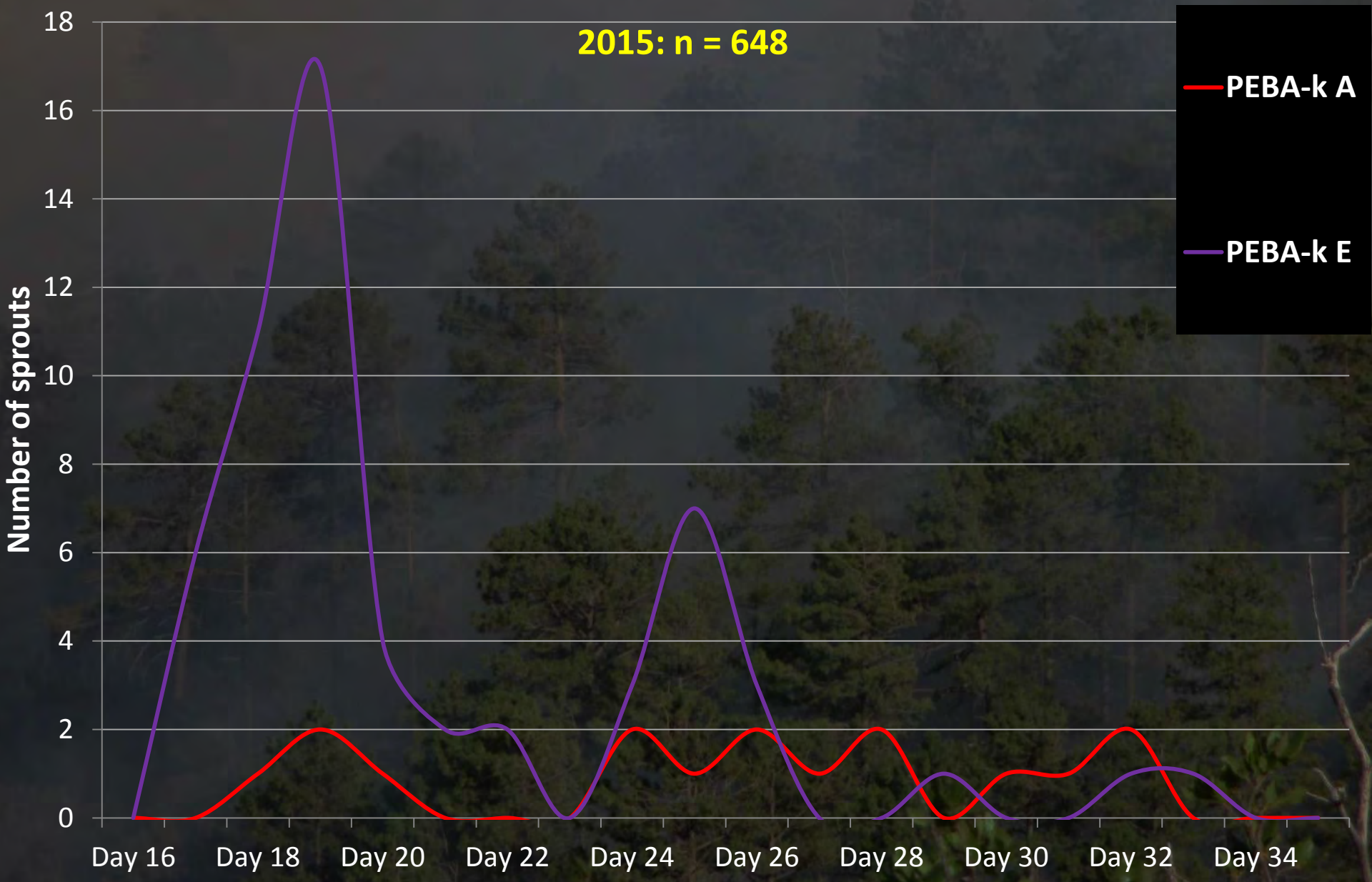

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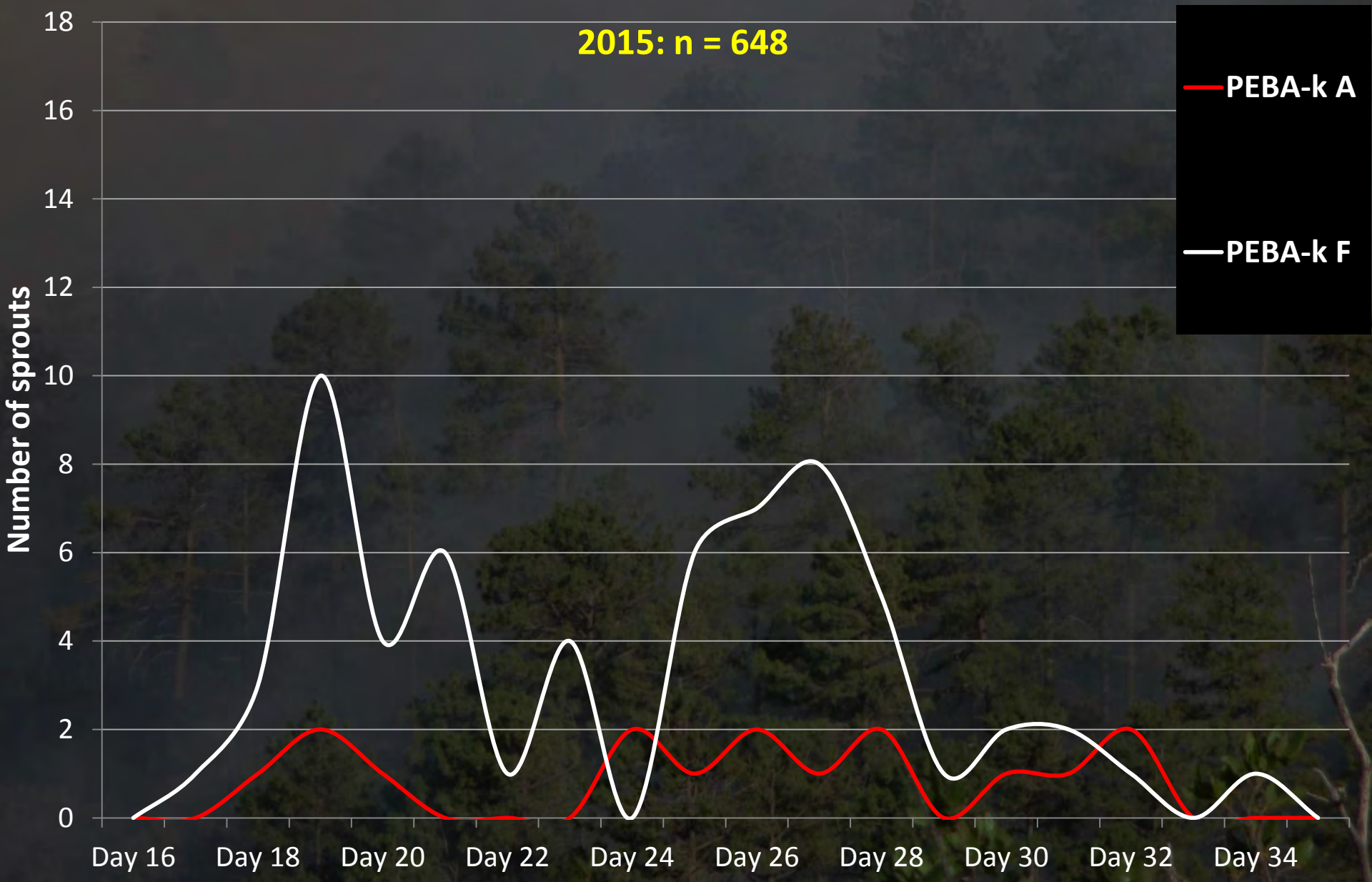

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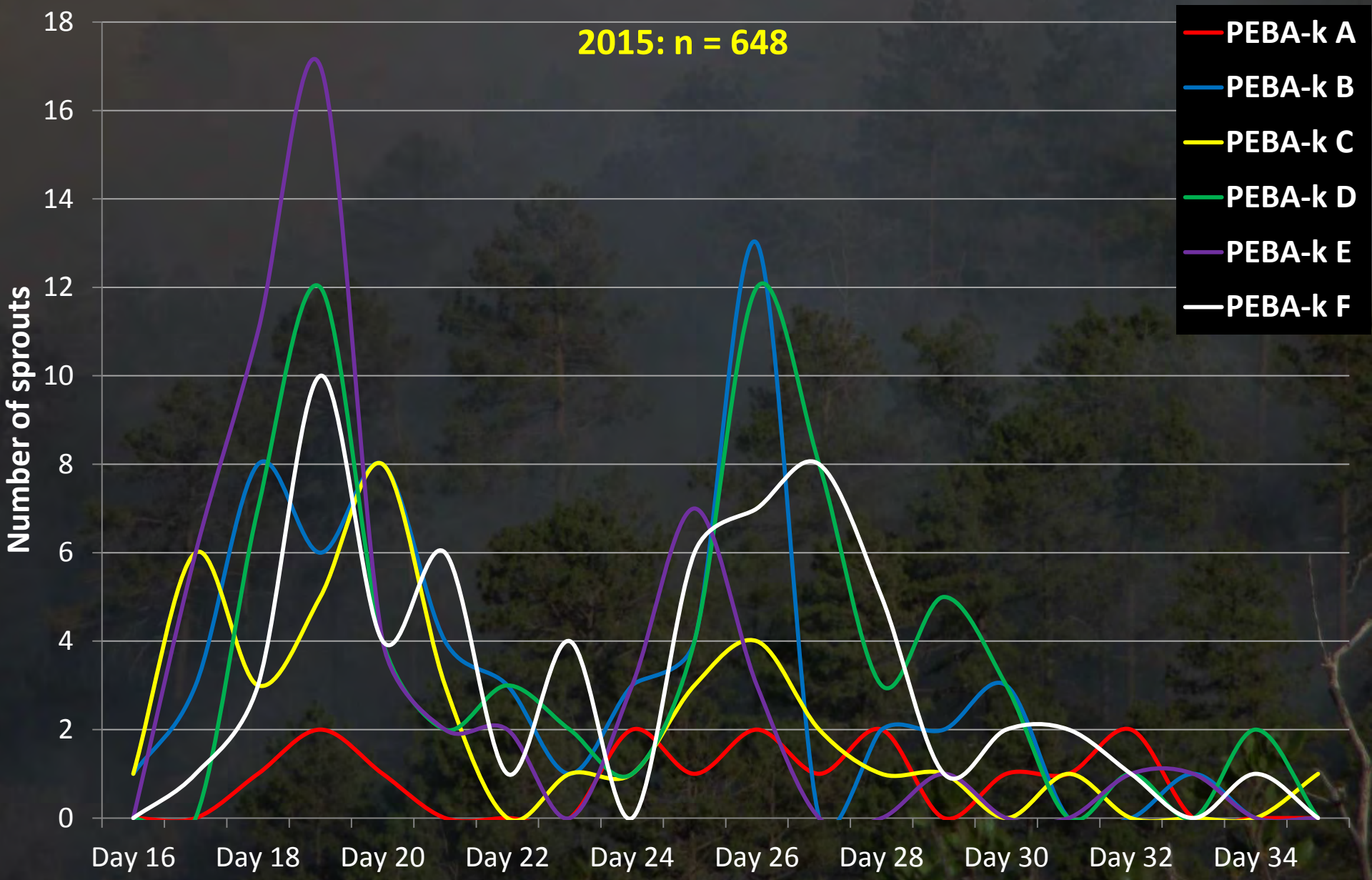

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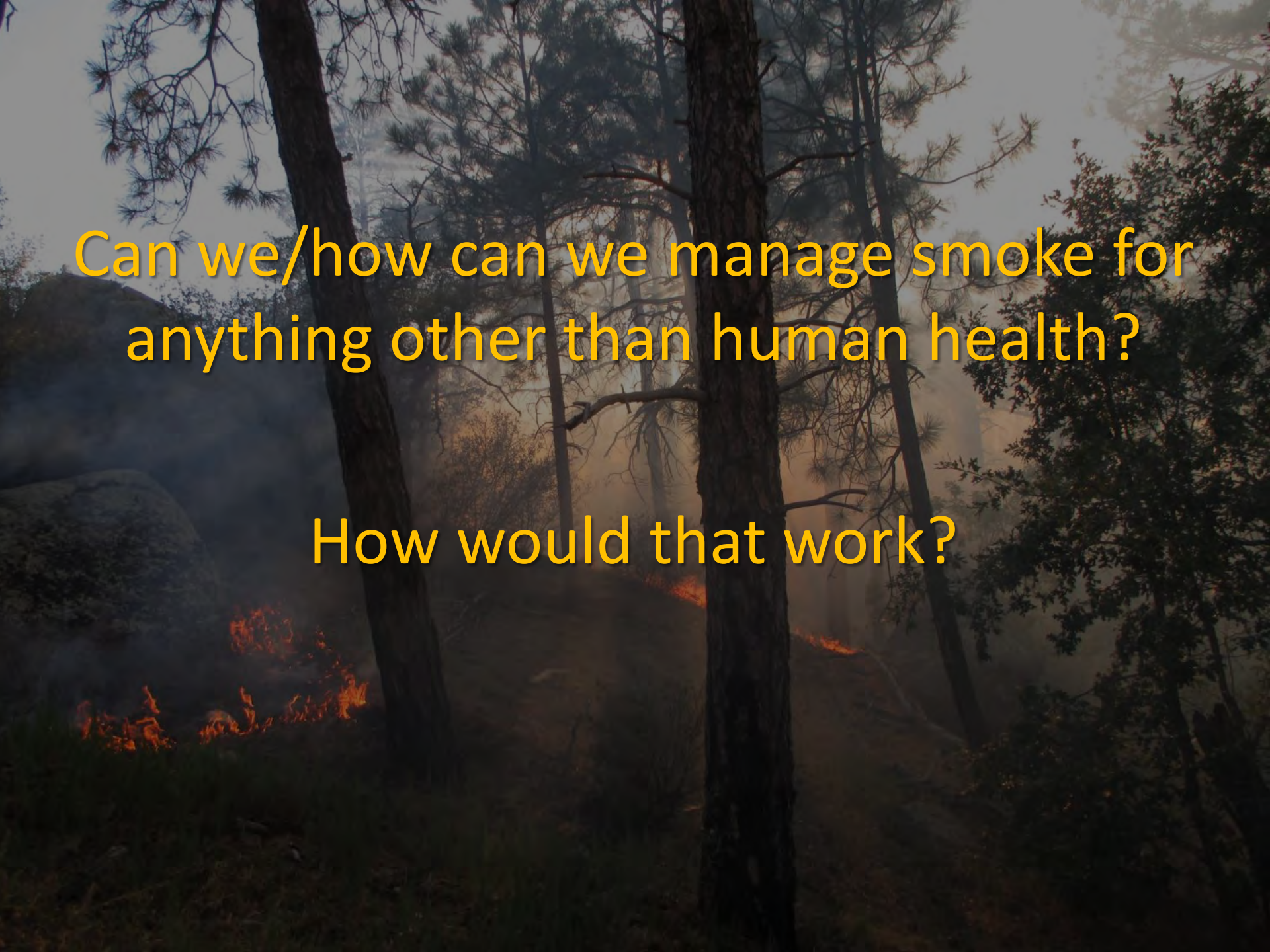
2) Affect the timing of the sprouting of native species adapted to frequent fire?
3) Affect the sprouting of native species if only the soil, and not the seeds, are exposed to smoke?
4) Is the response the same in different ecotypes?



Can we/how can we manage smoke for anything other than human health?

How would that work?

Mistletoe?

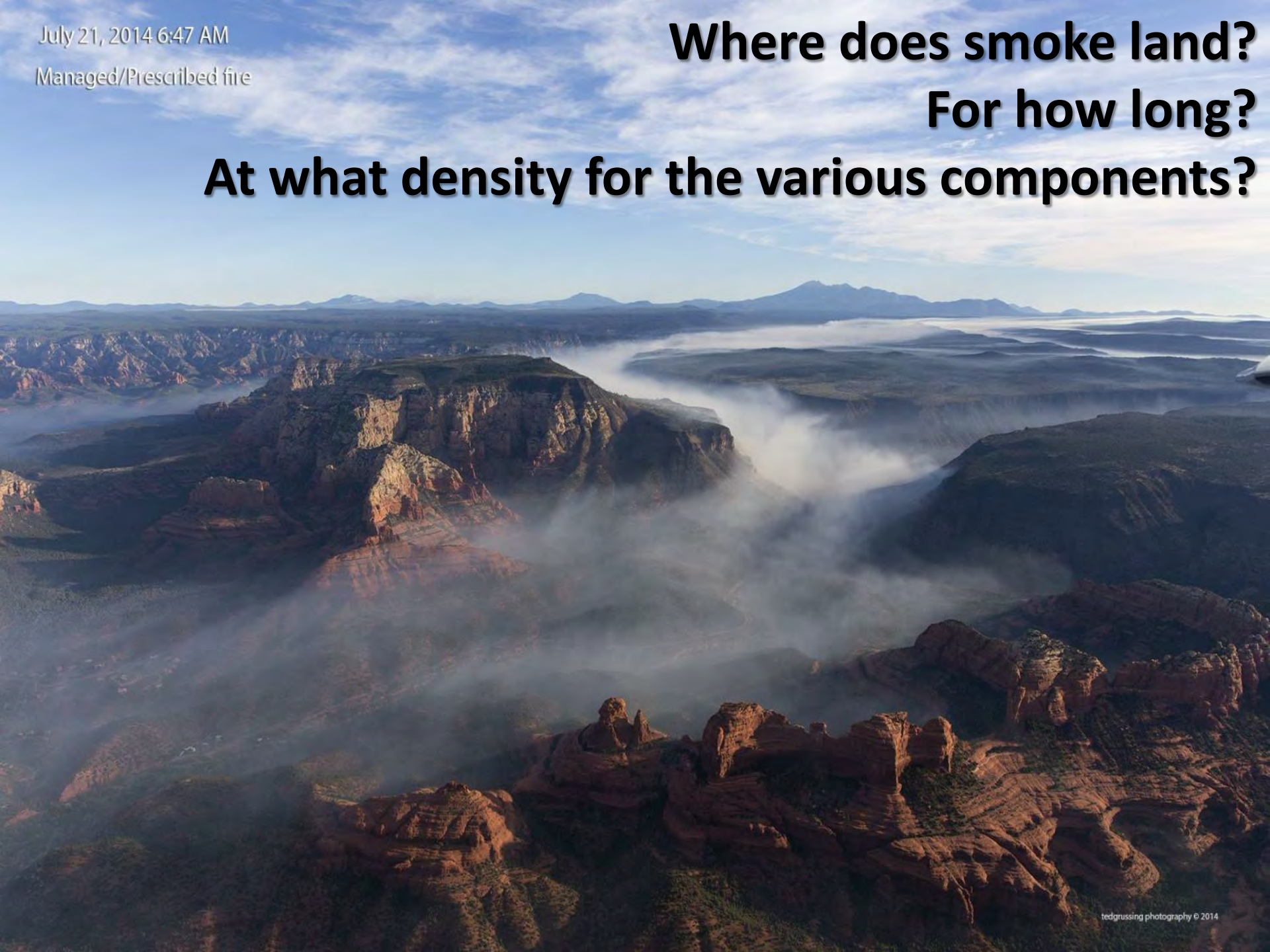
- Germination for three species of mistletoe was **inhibited** when seeds were exposed to smoke for 60 minutes or longer.
- For one species of mistletoe, seeds were **enhanced** after 30 minutes of smoke from **drier fuels** (effects of steam?)
- Pine seedlings innoculated with fungii (rust) showed reduced amounts of fungii when exposed to pine needle smoke

Critter adaptations?

- Insects?
- Reptiles?
- Mammals?
- Fish?
- Amphibians?
- Birds?

We know next to nothing about critters + smoke
…except for humans.

Where? When? Duration? Concentration?



Where does smoke land?
For how long?
At what density for the various components?

Conservation, Land Management, and other Implications

- Consider the effects of smoke and it's products (or the lack thereof) on invasive plant species known to inhabit specific areas
- Use to achieve maximum germination and/or establishment of native plants (BAER?)
- Consider shifts in species composition from the decrease or increase of smoke and it's products

Conservation, Land Management, and other Implications

The usual dilemma:

- The Clean Air Act considered smoke from wildland fires to be human-caused pollution, effectively limiting how much prescribed fire can be used
- Land management agencies are charged with managing for healthy landscapes…

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Questions?

Emission characteristics	Planned ignitions	Unplanned ignitions
Predictability of when smoke events occur	Predictable	Somewhat predictable to unpredictable
Predictability of the severity (concentration) of smoke impacts	Predictable	Somewhat predictable to unpredictable
Predictability of where there will be smoke impacts	Mostly predictable	Somewhat predictable to unpredictable (knowing where a fire will start)
Controllability of smoke	Mostly controllable	Mostly controllable to uncontrollable
Duration of smoke events	Days or weeks	Days, weeks, or months
Frequency of smoke events	Intermittent to frequent and increasing	Intermittent to frequent during the fire season, likely to increase
Severity/desirability of the effects of the fire	Mostly desirable	Mostly desirable to mostly undesirable
Longevity of negative effects	Short to moderate	Short to permanent
Extent of negative effects	Small, unlikely to be more than a few contiguous acres if it occurs	Variable, ranging from less than an acre to hundreds of thousands of acres
Potential for significant negative effects (other than smoke), such as downstream flooding or damage to infrastructure outside the fire perimeter	Low	Low to very high
Threat to human life and property	Low	Low to very high