

Research Article

Unburnt Grasstrees Adjacent to Burnt Grasstrees Are Twice as Likely to Flower as Unburnt Grasstrees Remote from the Burn, Implicating Smoke as the Flowering Stimulus

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Grasstrees are renowned for their ability to flower after fire. We show that unburnt grasstrees, *Xanthorrhoea preissii*, opposite a burnt site flower at twice the rate as those remote from the burnt site. This implicates smoke emitted from the fire reaching unburnt plants nearby and inducing flowering. The effect fell from the road edge by 2.5 times to reach negligible levels by 55 m, with flowering of the adjacent unburnt plants merging with the remote unburnt plants. The results are consistent with prolific flowering of grasstrees beside busy roads and the bioactive compound that smoke and vehicle fumes have in common is ethylene, a well known regulator of flowering.

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Background

Most *Xanthorrhoea* species only flower sporadically in the absence of fire, but abundantly 9–12 months after fire^{[1][2][3][4]}. There are reports of flowering by several herbaceous species at some distance from a burnt site^{[5][6][7]} or in the presence of smoke^[8]. Curtis^[1] observed extra flowering among *Xanthorrhoea australis* plants in unburnt stands and attributed this to smoke drift from fires up to 200 m away. There is some evidence that the causal agent is ethylene, routinely present in the smoke from bushfires or likely self-produced in response to damage^{[9][10][11]}. Thus, smoke rather than heat, foliage loss, or resource

amendment (light, nutrients, water, warmth)^[12] appear responsible for flowering in grasstrees, but this has never been examined formally.

Here, we aimed to test the hypothesis that it is smoke that stimulates flowering in grasstrees. Fire-stimulated flowering by the grasstree, *Xanthorrhoea preissii*, is well-studied^{[13][3][14][4]}. Prescribed burning of indigenous vegetation in which this grasstree is prominent is undertaken by the Western Australian conservation department. We expected this to provide areas that had been burnt, contiguous unburnt areas, and non-contiguous, but matched, unburnt areas, suitable for testing this hypothesis. We located such sites and the results are described here.

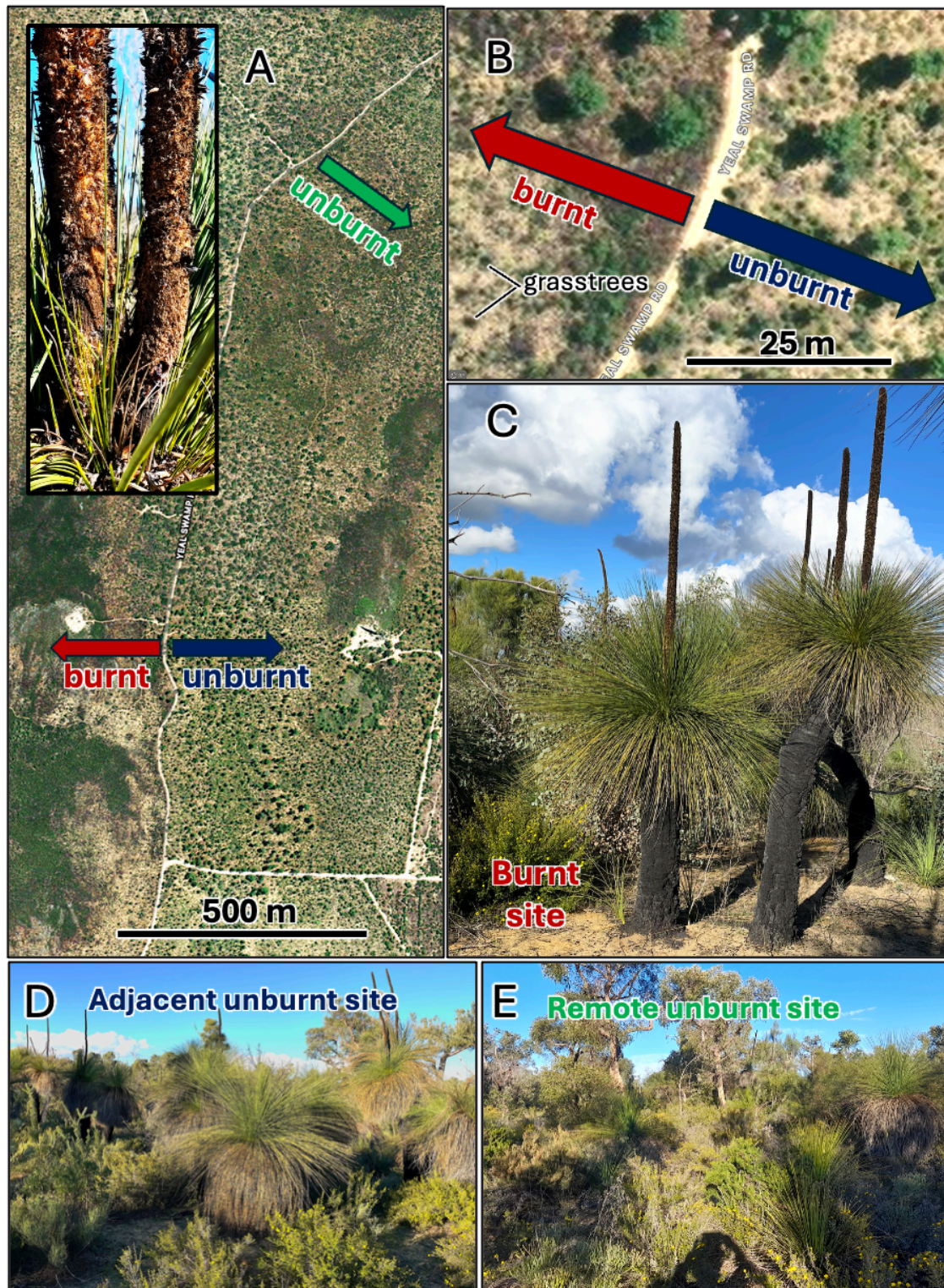


Figure 1. Images of study sites. A. Google map (1 Aug. 2026) of the study area showing locations of the three study sites. Inset: two identical spikes, 1.8 m tall, apparently arising from the same apical bud at the burnt site (we have never seen this before); B. Larger scale map showing open vegetation with scattered eucalypts and abundant xanthorrhoeas. C. Grass trees at the burnt site showing absence of a dead 'skirt', with the left plant

1.3 m tall; D. Adjacent unburnt site with grasstrees showing a well developed 'skirt', with central plant 0.7 m tall; E. Unburnt site 1 km away, with grasstree on the right 1 m tall and showing well-developed 'skirt'.

Methods

We located a patch of natural vegetation in Crown Land burnt by the Department of Biodiversity Conservation and Attractions in November 2025 on the west side of Yeal Swamp Rd, 55 km north of Perth, Western Australia (31.529° S, 115.714° E) (Fig. 1). On the immediate east side was vegetation last burnt 7 years ago (annual node count method of recovering *Hakea ruscifolia*, [15]). We located matched vegetation 1 km to the southeast that had not been burnt on both sides of the road for 7–8 years. The grasstree, *Xanthorrhoea preissii* (Asphodelaceae), was abundant at the first two sites, but sparser at the third. The vegetation was open eucalypt woodland (*Eucalyptus gomphocephala*, *E. marginata* with some *Allocasuarina fraseriana*) with a species-rich shrub layer to 1 m (*Hibbertia hypericoides*, *Acacia pulchella*, *Hakea* spp., *Conospermum stoechadis*, *Allocasuarina humilis* to name a few). The substrate was deep aeolian sand except the furthest burnt locations possessed occasional outcropping tamala limestone.

We set up two to three transects with tape measures extending to 75 m from the road edge over May–July 2026. We assessed all grasstrees within viewing distance from the tape progressively along the transect until 120–150 plants had been scored. As smaller plants are less likely to flower [14] we rejected those under 1 m tall. Each grasstree was assessed for a) distance from edge of the road, b) stature to the growing apex (from the estimated point of origin of the spray of leaves), c) number of branches, and d) number of inflorescences (from hereon called spikes).

The data were sorted into distance from the road, and the means taken for each successive group of 15 plants, to give 8–10 classes. Since flowering increases with increasing stature at a decreasing rate with an asymptote at about 2 m [14] we adjust for this biasing effect by dividing the mean number of flowering plants per class by the square root of mean plant stature per class. Percentage of flowering plants per square root of stature was plotted against distances from the road and standard curves applied, accepting the one that gave the highest coefficient of determination (R^2) as available from the statistics package, <http://vassarstats.net>.

For comparisons with the burnt population, the numbers of flowering and non-flowering plants were compared at the three sites. Plant stature and number of spikes were also compared to check if corrections for plant dimensions were required. Fisher's exact probability test to counts was applied to

the three groups to show statistical significance, and then pairwise comparisons undertaken to see where the differences lay. For the quantitative data, one-way ANOVA was applied to show statistical significance, and then Tukey's HSD test between the three pairs (<http://vassarstats.net>).

Results

Fig. 2 shows burnt plants were on average twice as likely to flower as adjacent unburnt plants, and that these were twice as likely to flower as remote unburnt plants. In terms of distance from the road, the burnt and unburnt plants showed no relationship. The plants adjacent the burn showed a declining relationship with the fitted line falling from 35% flowering at a mean of 5 m and 12% flowering at 70 m. The fitted line crossed the mean horizontal line for the remote unburnt site at the latter point, indicating a basal level of flowering here. Inspection of the data shows that the unburnt adjacent site more likely fitted a negative sigmoid (logistic) curve with a mean 32% flowering up to 55 m and 14% from there (measurements stopped at 75 m but the trend appeared to continue at longer distances).

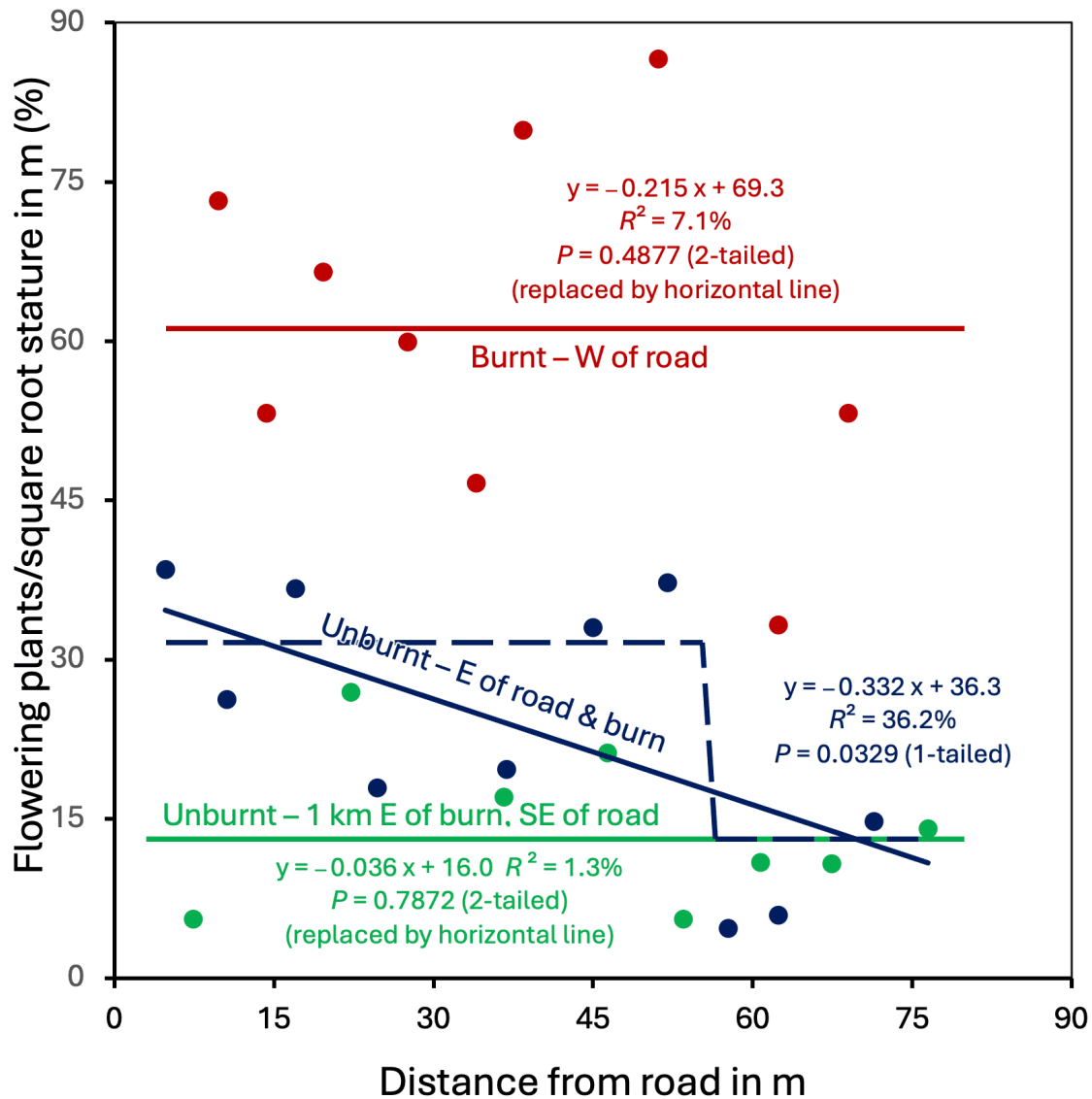


Figure 2. Flowering of *X. preissii* at the three study sites – burnt (red), adjacent unburnt (navy blue) and remote unburnt (green) – in relation to distance from Yeale Swamp Rd, Yanchep, Western Australia. As the burnt and remote unburnt sites showed no relation with road distance they are represented by horizontal lines (as their slopes are not significant even at 0.5 probability so any fitted line is misleading). Inspection shows that the adjacent unburnt site is more likely two horizontal lines (given here as broken) rather than a negative linear fit to the distance data.

Table 1 summarizes the results independent of distance from the road and shows that correcting for plant stature reduced the percentages (as the square root usually gave values > 1) but did not alter the pattern. The mean number of spikes per plant repeated the pattern with some indication of more spikes

per flowering plant among the burnt than control plants (4.6 times for spikes rather than 3.6 times for flowering plants). The plants at the three sites were matched morphologically as there was no significant difference in stature or branching. Even so, all results were corrected for stature as previous work has shown that flowering is dependent on height up to 2 m (Ward and Lamont

Grasstrees:	Burnt site	Unburnt adjacent burn	Unburnt remote from burn	Test	P
Sample size (total)	136	149	119		
% in flower	61.0 ^a	32.9 ^b	16.8 ^c	Chi-square	< 0.0001
% in flower corrected for stature (/sq rt m)	49.3 ^a	26.3 ^b	13.8 ^c	ANOVA/ Tukey's Not meet normality assumptions	< 0.001/ < 0.01/0.05
Mean no. of spikes per plant	0.83 ^a	0.38 ^b	0.18 ^c	ANOVA/ Tukey's Not meet normality assumptions	< 0.001/ < 0.01/0.05
Stature (m)	1.56 ^a	1.51 ^a	1.51 ^a	ANOVA	0.4412
% plants with multiple stems	12.5 ^a	12.1 ^a	10.9 ^a	Chi-square	0.9231

Table 1. Flowering, stature and branching of *Xanthorrhoea preissii* plants at Yeal Swamp Rd, Yanchep up to 75 m from the road. Multiple range tests (and pairwise tests in the case of the nonparametric flowering data) were applied to the three data sets for each variable assessed.

Discussion

Our results provide compelling, although indirect, evidence of smoke as the causative agent of flowering in response to fire by *Xanthorrhoea preissii*. Grasstrees at least 1 m tall were twice as likely to flower when adjacent to the burnt site as those 1 km away. Not only were the sites matched physiognomically but so were the plants morphologically (all with a mean stature of 1.5 m and 88% single stemmed). This means that the only relevant environmental difference between the two sites was the former's exposure to smoke. The burnt site was on the west side of the road. The standard fire-management protocol of the conservation department is to set fire along the road against the prevailing winds. This means smoke would have blown approximately east across the adjacent unburnt site to reach the hundreds of grasstrees there.

Further, the effect decreased with distance from the road, with a mean of 35% at 5 m and 11% at 75 m, the limit of the transects. No such linear or curvilinear trend was observed for the burnt and remote unburnt sites. By 70 m, flowering at the adjacent and remote unburnt sites had merged at a mean of 14%. Inspection of the data showed that the relationship was more likely a negative sigmoid, with a sudden drop at 55 m from a mean of 32% to 14%. A likely interpretation is that smoke was no longer at sufficient concentration to stimulate flowering by then. In contrast, the anecdotal observation by Curtis^[1] of flowering by *Xanthorrhoea australis* was still evident 200 m from the burnt site.

The volatile hydrocarbon, ethylene, is not only a standard component of smoke but a universal growth regulator in plants, especially in relation to flowering^{[11][10][16]}. Gill and Ingwersen^[9] reported a personal communication of ethylene as well as their own work on burning promoting flowering in *X. australis*, consistent with our results. Ethylene is most likely to be highest in the immediate vicinity of burnt plants and charred leaves containing ethylene could even fall onto the apex. This would explain why the burnt plants flowered twice as much (61%) as the adjacent unburnt plants.

Lamont and Groom^[4] recently reported prolific flowering of *X. preissii* beside a major road 65 km south of the current study. They attributed this unique phenomenon to the presence of exhaust fumes from the vehicular traffic, specifically ethylene, a major component of spent fuel (Duffy et al. 1999, Cai and Xie 2009, Fukusaki *et al.* 2021). They drew a parallel with fire promoting flowering in this species and the anecdotal evidence that the causative agent was ethylene in smoke. Our new work shows that smoke is indeed the most likely source of bioactive compounds responsible for inducing flowering. The common link is ethylene.

Other aspects of that study are of interest in relation to the current one: a) there is a gradient of diminishing effect on flowering relative to the distance of the source, b) more precisely, there appears to be a disjunction in the gradient that might represent a critical level of flower-promoting ethylene beneath which its stimulatory effect is negligible as its concentration continues to fall with increasing distance from the road. This was only at 10 m in the road traffic study but might be consistent with the expected much lower levels of ethylene produced by vehicles. c) if it is heavy vehicle traffic that is responsible for promoting flowering then there should be no road effect at our Yanchep site as only two vehicles used the road during our visits (although many motorbikes did in the weekend), compared with the many hundreds per hour at the Redmond Reserve site; and indeed both the burnt and remote unburnt sites showed no relationship with distance from the road. d) there was no difference in stature of plants in relation to the road in both studies confirming no difference in growing conditions due to a

possible road effect (runoff, less competition, more light), contrary to some other studies at more resource-limited sites^[17].

The adoption of a gradient approach and morphological and site matching have reduced the need for site replication in both studies, especially as the results are so clear cut and supportive of the hypotheses. Nevertheless, it would be instructive to confirm these patterns at other sites in the quest for generality. Both studies point to a critical role for ethylene in promoting flowering of grasstrees and this must be the focus of future studies. This study was unfunded and conducted in our free time but deserves more formal support in view of its potentially important contribution to both plant science theory and application. For example, should the role of ethylene in promoting flowering in grasstrees be confirmed then this opens the way for inducing cultivated grasstrees to flower, as is routine in the pineapple industry^[16].

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Declarations

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