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Cold sensitivity of *Casuarina cunninghamiana* (*Casuarinaceae*) saplings

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Casuarina cunninghamiana (*Casuarinaceae*) fidanlarının soğuğa duyarlılığı

Abstract: The Australian tree, *Casuarina cunninghamiana* Miq. (*Casuarinaceae*), is widely planted for agroecosystem and other benefits, and belongs to a family (sheoaks) with wide adaptation and tolerance to environmental extremes. However, extreme cold as a stressor is not common on the Australian continent, so compared to heat and drought, less work has been done on the cold tolerance of Australian flora. Therefore, saplings of *C. cunninghamiana* were exposed to 0 to 4 months of extreme winter temperatures below -5°C to about -15°C over 2 years in Niğde, Central Anatolia, Turkey to test their cold sensitvity. Damage was severe, however, most plants exposed to 1 or 2 months of the milder temperatures (down to -5°C) at the beginning of winter recovered. Four months exposure killed all the plants. However, even the milder, early-winter conditions are unlikely to be suitable for the long-term productivity or survival of *C. cunninghamiana* and perhaps all members of its family. The risk of extreme cold needs to be considered when planting sheoaks beyond their native range.

Key words: Abiotic stress, *Casuarina*, cold tolerance, frost damage, sheoaks

Özet: Avustralya ağacı, *Casuarina cunninghamiana* Miq. (*Casuarinaceae*) geniş bir adaptasyon ve çevresel uç noktalara toleransı olan bir familyaya (demirağacıgiller) ait olup, agroekosistem ve diğer faydalar için yaygın olarak yetiştirilmektedir. Bununla birlikte, Avustralya kıtasında aşırı soğuk bir stres etkeni olarak yaygın olmadığından, Avustralya florasının soğuğa toleransı üzerinde ısı ve kuraklığa kıyasla daha az çalışma yapılmıştır. Bu nedenle, *C. cunninghamiana* fidanları, soğuk toleranslarının belirlenmesi için Niğde'de (Orta Anadolu, Türkiye) 0 ila 4 ay süreliğine -5°C'nin altında ve yaklaşık -15°C'ye kadar aşırı düşük kış sıcaklıklarına 2 yıl boyunca maruz bırakılmıştır. Hasar şiddetli olmakla birlikte, kış başlangıcından itibaren 1 veya 2 ay daha ılıman sıcaklıklara (-5°C'ye kadar) maruz kalan bitkilerin çoğu toparlanmıştır. Dört aylık maruz kalma, tüm bitkilerin ölümüne neden olmuştur. Bununla birlikte, daha ılıman, erken kış koşullarının bile, *C. cunninghamiana*'nın ve belki de bu familyaya ait diğer tüm türlerin uzun vadeli üretkenliği veya hayatta kalması için uygun olması pek olası değildir. Kendi doğal aralığının ötesinde demirağacıgilleri dikerken aşırı soğuk riskinin dikkate alınması gerekmektedir.

Anahtar Kelimeler: Abiyotik stres, *Casuarina*, soğuğa tolerans, don hasarı, demirağacıgiller

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1. Introduction

Australian plants have evolved with tolerance to a range of environmental extremes including extended drought, high temperatures, infertile or saline soils, and more (Turnbull, 1997). However, cold as a stressor is not particularly severe in Australia (Riley and Saygı, 2021), so Australian flora has not commonly been assessed for its cold sensitivity even though many species are now grown globally for economic and other benefits often under conditions that differ from their native range. The Australian sheoaks (*Casuarinaceae*) are an important group of actinorhizal plants that of potential use in agroecosystem in semiarid contexts, where conditions might be much colder than in Australia (Riley, 2019). However, there is limited data on their sensitivity to extreme cold. *Casuarina cunninghamiana* Miq. (river sheoak) was assessed for frost damage in California, USA and found to be potentially tolerant to -8°C but severely damaged at lower temperatures to -13°C (Merwin et al., 1995), but these data were only collected opportunistically after a few brief, extremely cold weather events, and no information was collected on recovery. More recently, it was reported that diaspore release from *C. cunninghamiana* is sensitive to freezing (Riley and Saygı, 2021) indicating freezing can mechanically damage the woody tissues of sheoak infructescences.

The objective of this study was to assess the cold sensitivity of *C. cunninghamiana* by exposing saplings to natural subzero winter temperatures for 0 to 4 months in Niğde, Central Anatolia, Turkey.

2. Materials and Methods

This study examined the sensitivity of container-grown *C. cunninghamiana* saplings when exposed to 0 to 4 months of natural subzero winter temperatures in Niğde, Turkey (37°56′37″N, 34°37′51″E; daily minimums for the 2 years of the are presented Figure 1, with both years having a similar pattern of temperatures. Seed of *C. cunninghamiana* (the common species in Turkey; Riley and Korkmaz, 2019) was sourced from Antalya, Turkey in October 2018 (36°53′06″N, 30°40′54″E) and plants grown in a greenhouse in a mixture of local soil and peat (1:3) repotting into square plastic pots (115 × 183 mm) at least six months before the first experiment in 2019. Fifty of these plants (mean height ~0.7 m) were arbitrarily allocated five groups of 10 (Fig. 2a) that were exposed to natural winter conditions for 0 to 4 months commencing 5 November 2019. The pots were fully imbedded into the field soil to prevent them freezing and to keep the plants upright (positions formally randomised in four blocks), and watered at least weekly. The experiment was repeated commencing 6 November 2020 with six plants per group

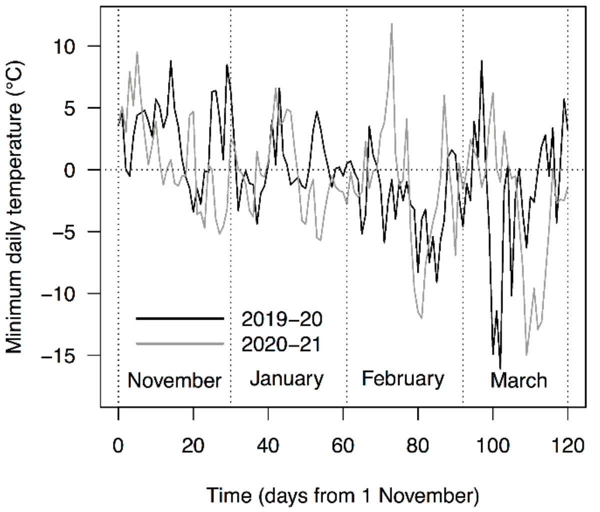

Figure 1. Minimum daily temperature in Niğde, Turkey (government weather station, 37°57′30″N, 34°40′46″E) for November to February 2019-20 and 2020-21

(mean height ~1.9 m; Fig. 2a) having been repotted into 300-m circular pots in mid-2020. When placed in the field (likewise randomised in four blocks), these pots were surrounded and covered with straw to prevent freezing and watered at least weekly. In both years, the plants were regularly examined of symptoms of frost damage and height (stem length) measured, and recovery monitored for 4 to 1 months after returning to the greenhouse for the 1- to 4-month exposure groups, respectively, with the final observations made in April. Data were analysed and visualised with R version 4.1.0 (R Core Team, 2021).

3. Results

In both years, nearly all foliage was frost damaged and had turned brown by early December having been exposed to minimums mostly above -5°C. With extended cold exposure, some damaged foliage and small branchlets were shed, and the main stems became bent with loss of mechanical strength exacerbated by snowfall events (Fig 3). The plant height decreased with longer exposure in both year (Fig. 2b,d), consistently for all exposure groups in 2019-20, but in 2020-21 with plants having stronger stems, the decrease in height was most evident in the longest exposure group. The control group (0 months exposure) continued to grow in the greenhouse (especially the younger plants) despite short day lengths and temperatures being typically below 20°C as the heating system did not fully compensate for the subzero ambient temperatures. Recovery (defined as an new shoot growth) in 2019-20 (recorded in April) was only observed in 8 and 6 of the 10 plants with 1 and 2 months of cold exposure, respectively (Figs 2c and 3a). In 2020-21, recovery was monitored from 1 month after returning plants to the greenhouse with half or more recovery occurring within a month and all recovery within 2 months for plants exposed for 1 and 2 months (Fig. 2c). Only one plant recovered after 3 months cold of exposure. These results were similar the first year (Fig 3b), but with a greater proportion recovering. Recovery (reshooting) mostly occurred along the entire stem but in a few plants, new shoots only developed at the base of the stem.

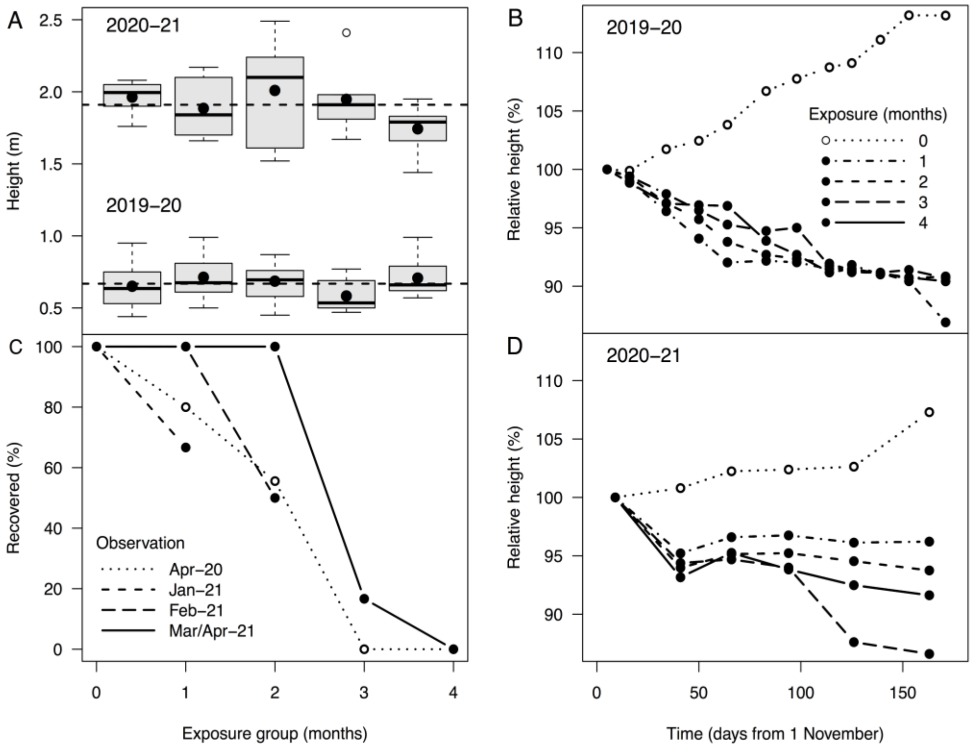

Figure 2. A. *Casuarina cunninghamiana* sapling height (main stem length) box plots for five low-temperature exposure groups for 2019-20 (n = 10) and 2020-21 (n = 6). Group means (black circle) were not significantly different (ANOVA, p = 0.05), however, subsequent heights are presented relative to the initial value to eliminate inter-plant variation. **B, D.** Mean relative height for saplings exposed to 0 to 4 months of natural subzero temperatures in the field in Niğde, Turkey, 2019-20 and 2020-21, respectively. **C.** Proportion of recovered plants in 2019-20 in April (1 month after the last group was returned to the greenhouse) and 2020-21 (1 month after each group was returned to the greenhouse). Recovery was defined as any fresh shoot growth indicating that the plant was alive.

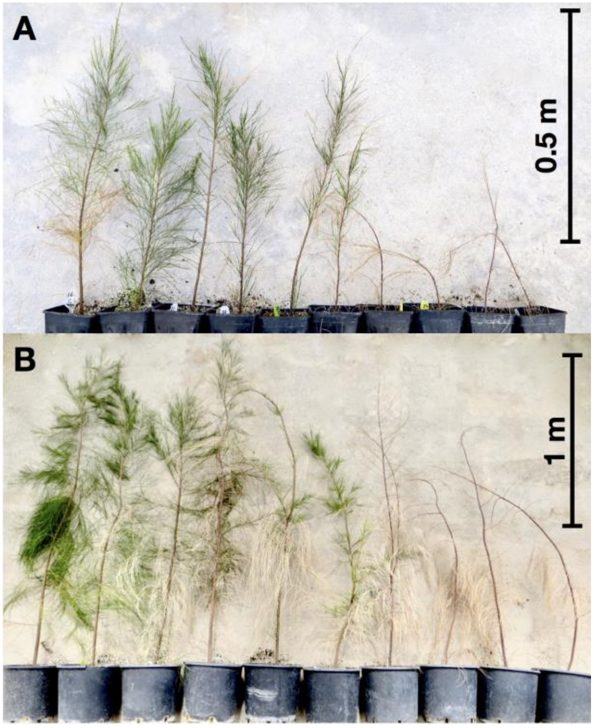

Figure 3. *Casuarina cunninghamiana* saplings of five low-temperature exposure groups from **A**, 2019-20, and **B**, 2020-21 (from right to left, 2 arbitrarily selected plants from each group of 0 to 4 months exposure) about months after return to the greenhouse. Although the photograph was taken about a month after (late April an and early May, respectively) the final observations presented in Figure 2c, no additional plants had recovered.

4. Discussion

These findings indicate that *C. cunninghamiana* is not tolerant to extended periods subzero temperatures, and clearly not extremely cold conditions, as experienced in the experimental site in January and February. It is not possible from these data to fully distinguish between degree and duration of cold exposure because the temperatures continued fall across 4 months (Fig. 1). However, the damage that occurred with only 1 month of cold exposure (November) was still quite problematic, with most foliage and some branchlets damaged, so even 1 month per year of such weather is likely to prove unsuitable for long-term productivity or survival of *C. cunninghamiana*. Therefore, it is concluded that *C. cunninghamiana* is unlikely to survive in areas where winter temperatures frequently drop to and below -5°C (consistent with the observations of Merwin et al., 1995). It is also highly probably that all members of the family are similarly cold sensitive having consistent morphology and anatomy. In addition, with global warming, extreme weather events will potentially become more frequent and, counterintuitively, this include extreme cold events as experienced in Texas, USA in February 2021 (Doss-Gollin et al., 2021). This means that even *C. cunninghamiana* planted in midlatitudes with mild winters could be subject to unanticipated damage from such events, and the risk of extreme cold needs to be considered when planting sheoaks beyond their native range.

Conflict of Interest

Authors have declared no conflict of interest.

Authors' Contributions

The authors contributed equally.

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