Contrasting physiological traits of shade tolerance in *Pinus* and *Podocarpaceae* native to a tropical Vietnamese forest

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Introduction

The absence of pines from tropical forests is potentially explained by their traits of shade intolerance. However, *Pinus krempfii*, a flat-leaved pine, seems to compete successfully with shade-tolerant tropical species. A research study was conducted in the Central Highlands of Vietnam to test the hypothesis that successful conifer performance at the juvenile stage depends on traits of shade tolerance by comparing the physiological characteristics of *P. krempfii* to species from two taxa: the genus *Pinus* and the family *Podocarpaceae* (shade-tolerant conifers often found in pantropical mountain forests).
Data was collected on leaf photosynthetic, respiratory and biochemical traits (Schmiege et al, 2020).

Using this data, statistical tests were performed to answer the following questions:
Do these 7 species of *Pinus* and *Podocarpaceae* respond differently to lower levels of light?
Where does *Pinus krempfii* fall in comparison of these two genera?
Does Vcmax predict Jmax and does this relationship differ between the 7 species?

Methods

Publicly available data was retrieved from the Dryad Database[1] and was analyzed with R v4.2.2[3].

Table 1 Physiological trait measurement terms defined[2]

Amax	light-saturated photosynthesis rate in micromol m^{-2} s^{-1}
Jmax	maximum electron transport rate in micromol m^{-2} s^{-1}
Vcmax	maximum carboxylation rate in micromol m^{-2} s^{-1}

Table 2
Characteristics of the conifers of the Central Highlands of Vietnam[2]

	Species (Family)	Leaf morphology	Shorthand name
	*Pinus kesiya* (Pinaceae)	Needle	pike
	*Pinus dalatensis* (Pinaceae)	Needle	pida
	*Pinus krempfii* (Pinaceae)	Flat	pikr
	*Dacrydium elatum* (Podocarpaceae)	Needle / Imbricate	dael
	*Dacrycarpus imbricatus* (Podocarpaceae)	Flat / Imbricate	daem
	*Nageia wallichiana* (Podocarpaceae)	Flat	nawa
	*Podocarpus neriifolius* (Podocarpaceae)	Flat	pone

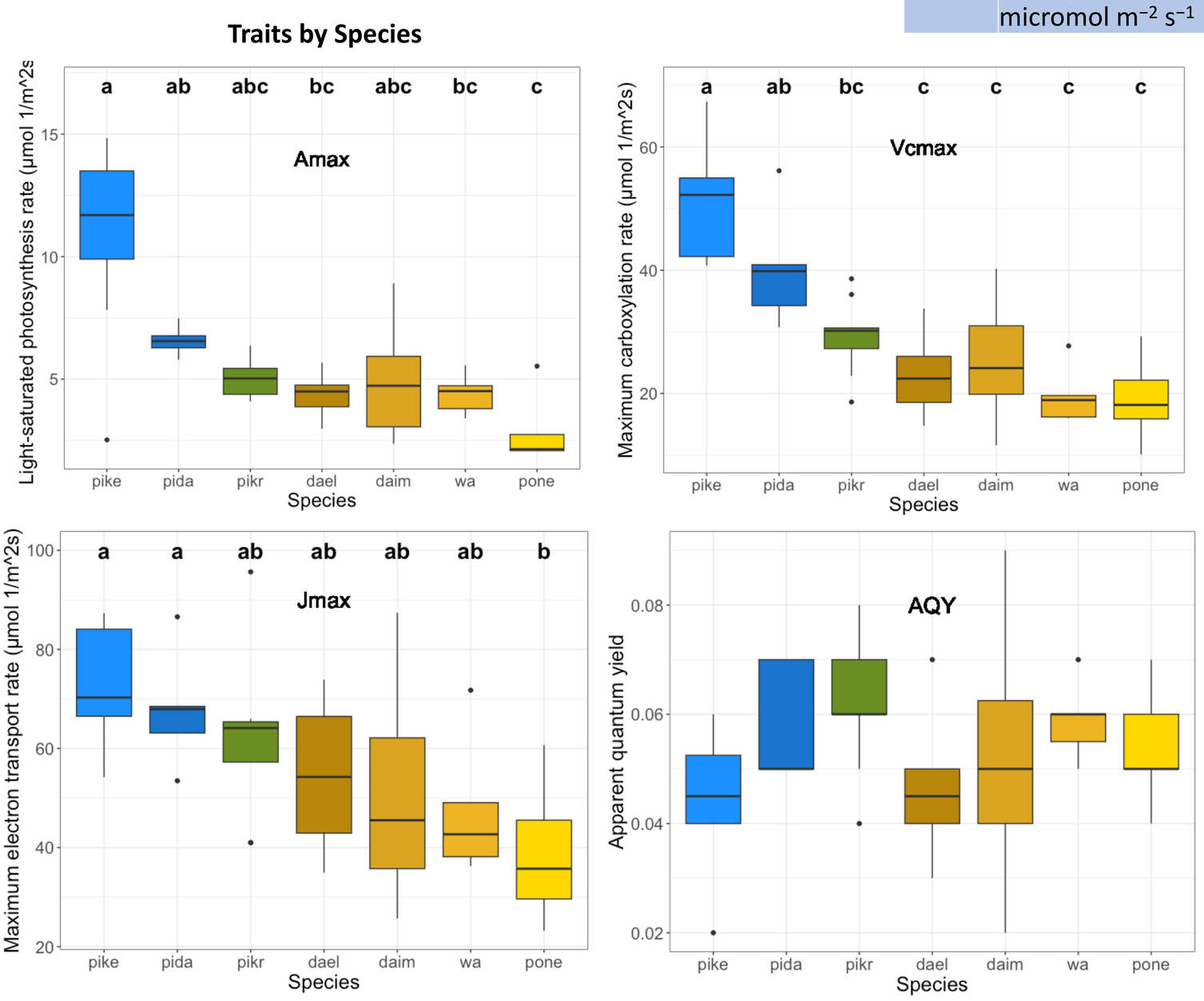

Figure 1 There is a significant difference of at least one species for Amax, Jmax, and Vcmax. There is no significant difference between species for AQY.

Since Amax data did not pass assumptions of normality for ANOVA, the Kruskal-Wallis rank sum test was used (X^2 = 23.83, df = 6, $p < 0.001$). Amax for pike was different than dael and pone. Amax for pida was also different from pone.

ANOVA testing was used for Jmax by species ($F_{6,41}$ = 4.11, p = 0.003). Jmax for pone was different than pike and pida.

ANOVA testing was used for Vcmax by species ($F_{6,41}$ = 17.39, $p < 0.001$). Vcmax for pike was different than pikr, dael, daim, wa, and pone. Vcmax for pida was different than dael, daim, wa, and pone.

ANOVA testing was used for AQY by species ($F_{6,43}$ = 1.68, p = 0.15). There was no significant difference between species.

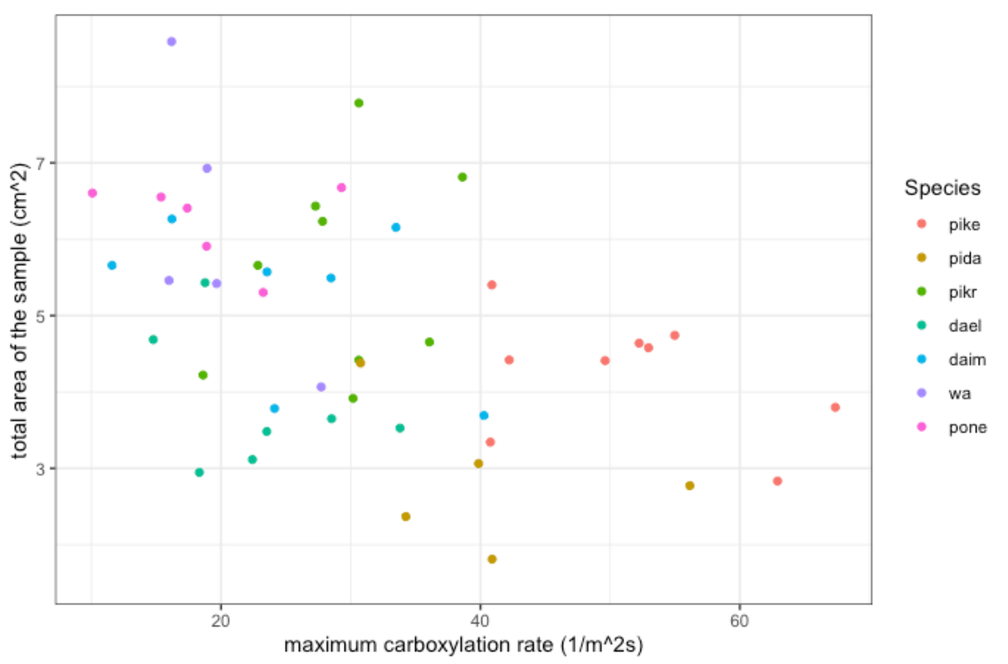

Figure 2 Pearson's test was used to test the correlation of Vcmax and total area of the sample. A significant negative relationship was found.
Correlation coefficient = -0.45, df = 46, p-value = 0.001

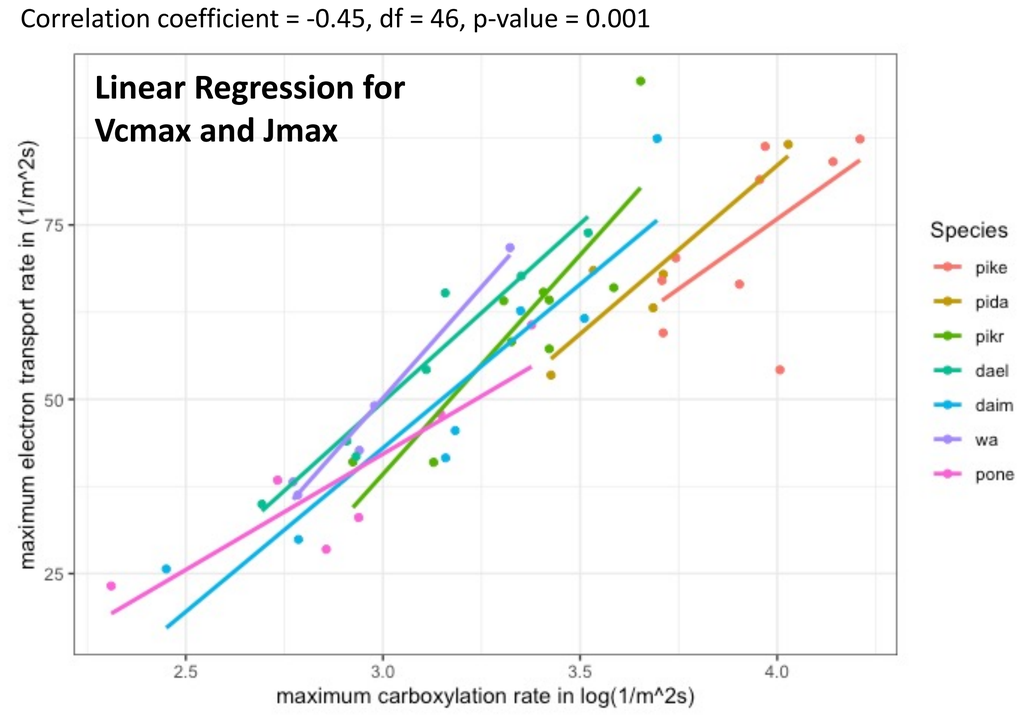

Figure 3 A significant positive relationship was found between Vcmax and Jmax and a linear regression model was preformed on the two. It was found that Vcmax predicts Jmax (t-value = 12.46, df = 46, $p < 0.001$). Although Vcmax and Jmax individually differ between species, the relationship of Vcmax and Jmax was not found to significantly differ between species.

[1]Schmiege, Stephanie, et al. "Data from: Contrasting Physiological Traits of Shade Tolerance in Pinus and Podocarpaceae Native to a Tropical Vietnamese Forest: Insight from an Aberrant Flat-Leaved Pine." *Dryad*, Dryad, https://datadryad.org/stash/dataset/doi:10.5061/dryad.1g1jwstss.
[2]Schmiege, Stephanie C, et al. "Contrasting Physiological Traits of Shade Tolerance in *Pinus* and Podocarpaceae Native to a Tropical Vietnamese Forest: Insight from an Aberrant Flat-Leaved Pine." *Tree Physiology*, vol. 41, no. 2, 2020, pp. 223–239., https://doi.org/10.1093/treephys/tpaa123.
[3]R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.