



Using CSR theory
for selecting woody
plants for urban
environments

Drs Andrew Hiron,
Henrik Sjöman &
Harry Watkins



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Myerscough



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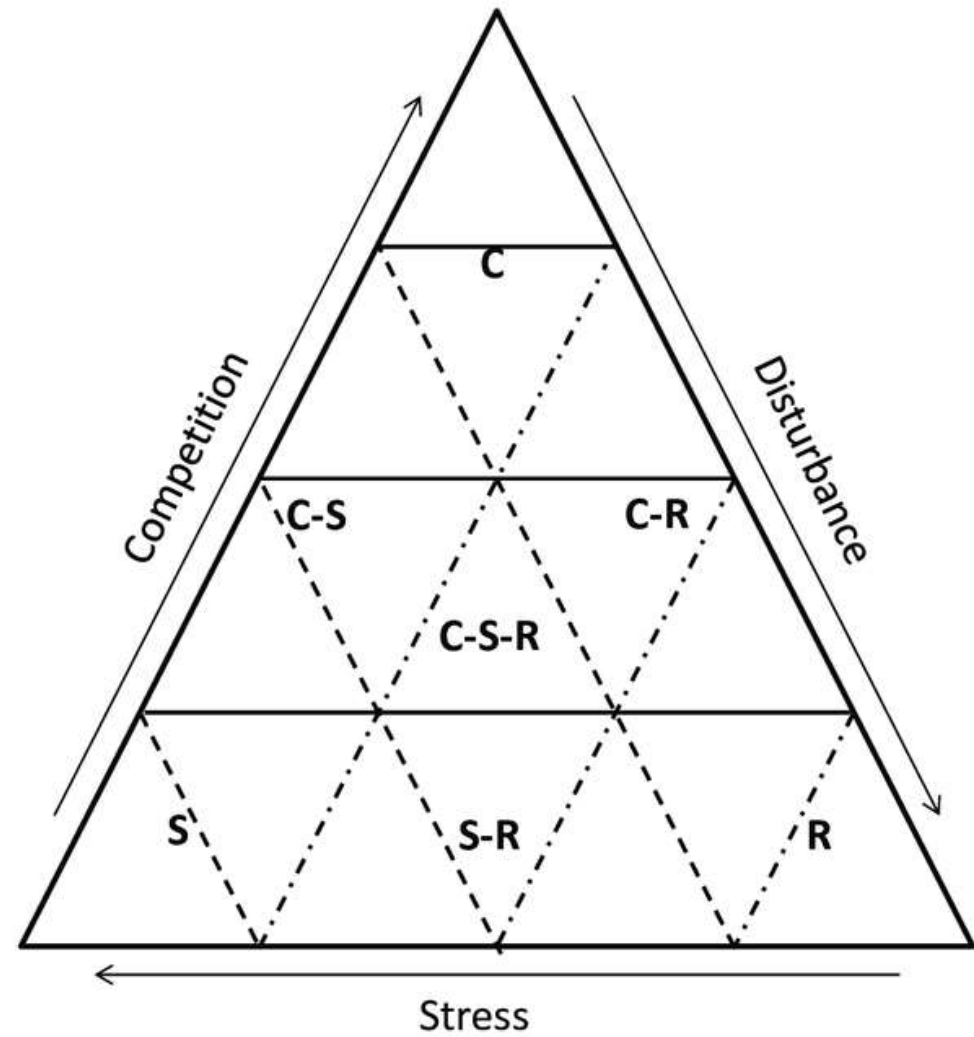
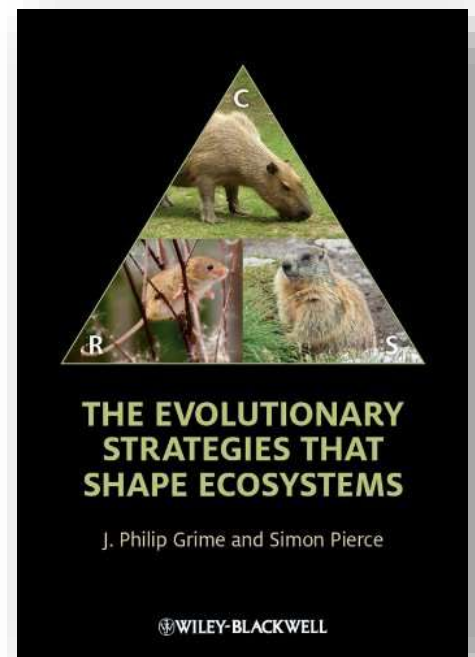
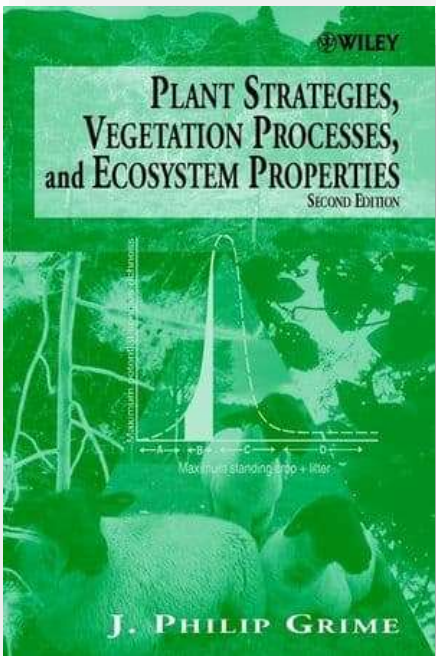
How do we improve selection decisions?

- Ecological theory
- Ecophysiological strategies
- Trait based assessment
- Biogeographical data analysis





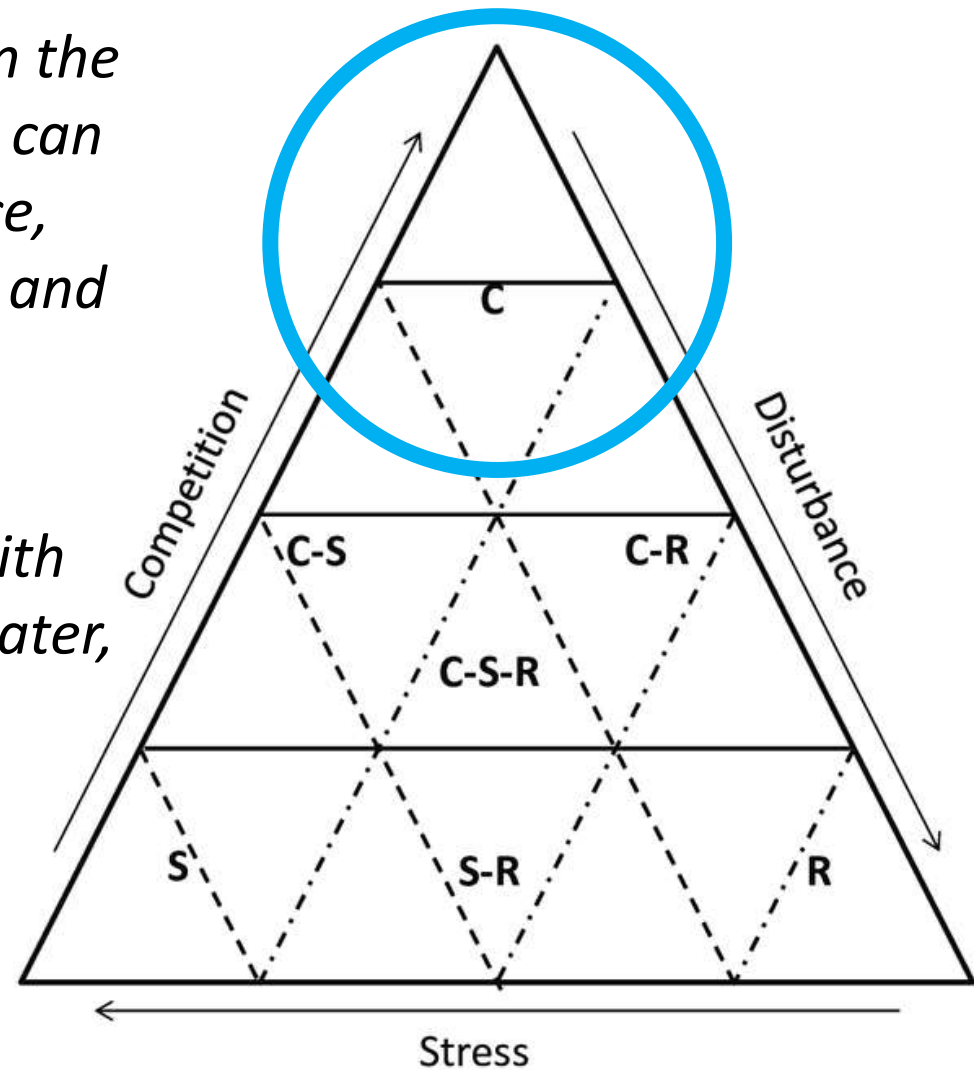
Roots of ecological theory



Competitors | C-Strategists

C-strategists are species that in the best and quickest way possible can assimilate the energy and space, both above and under ground, and by doing so get an advantage through powerful growth.

These trees grow in habitats with high amounts of resources – water, nutrient etc. In dry and poorer habitats these species are less competitive.

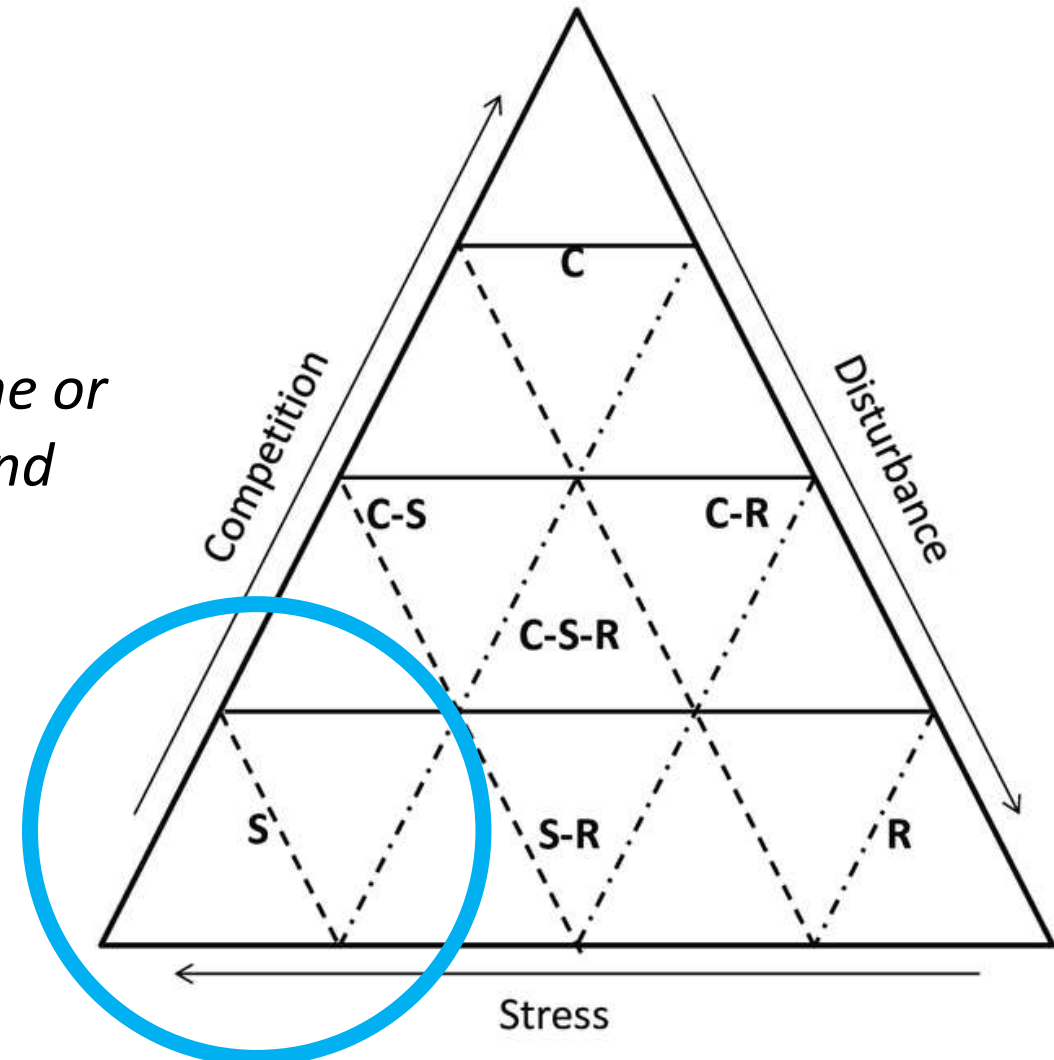


Pterocarya fraxinifolia



Stress tolerators | S-Strategists

***S-strategists** can be tolerant to one or several stress factors e.g. warm and dry habitats, cold temperatures, shade etc.*





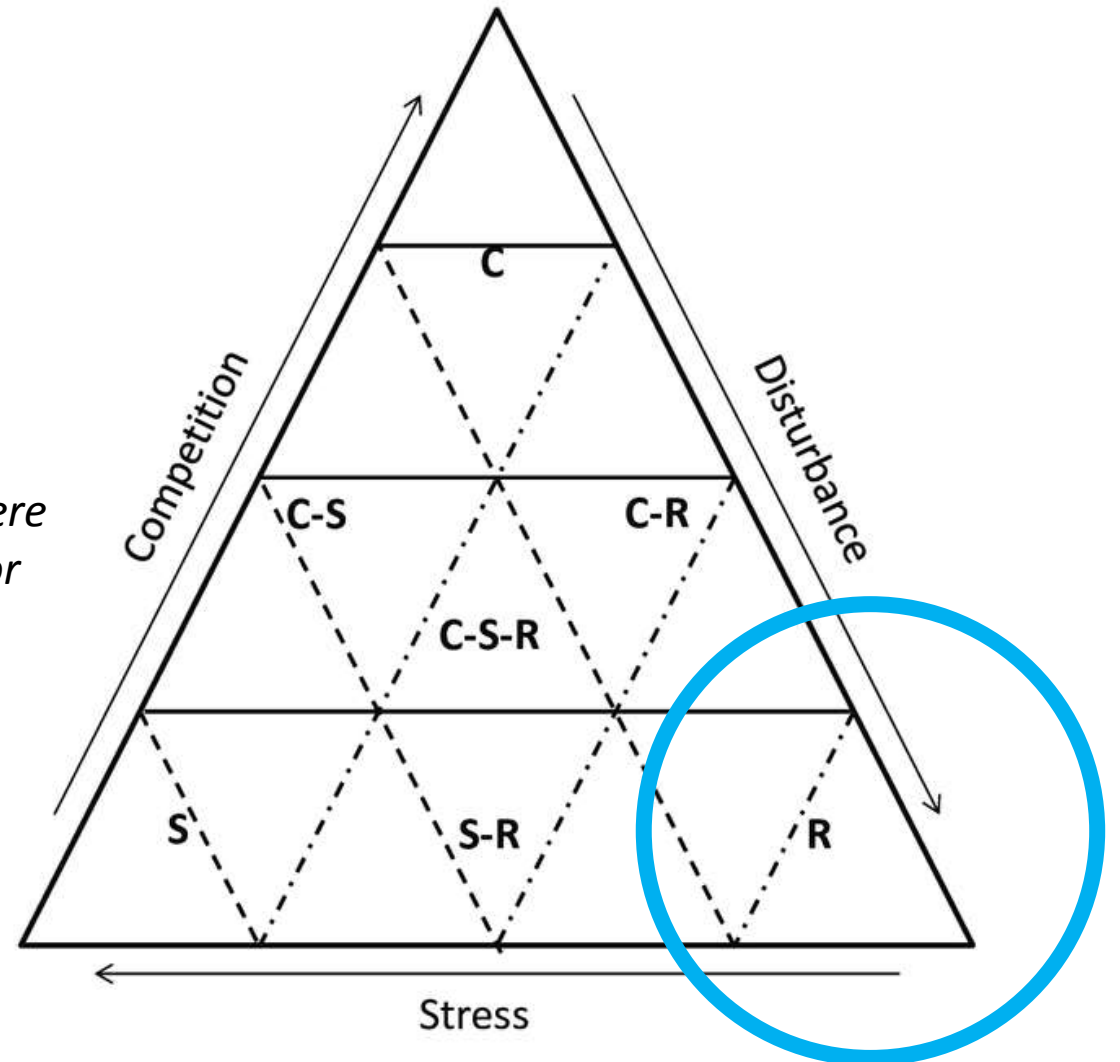




Viburnum lantanoides

Ruderals | R-Strategists

R-strategists thrive in disturbed ecosystems where they can quickly establish themselves in young or disturbed vegetation system.





Allocating CSR plant functional types: the use of leaf economics and size traits to classify woody and herbaceous vascular plants

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Summary

1. Three main directions of adaptive specialization are evident in the world flora, reflecting fun-

damental trade-offs between leaf economics and size. The current method, cannot be applied to it.

2. We aimed to produce a general...

3. Principal components analysis, gymnosperm and its space occupied by function PCA axes and values of leaf history, specific leaf area (S specific leaf area) were could be compared against ternary coordinates and test SLA values.

4. The method allowed us to Grime's theoretical CSR between species within general with previous methods.

5. Rapid CSR classification tally allowing primary plus landscape scales.

Key-words: adaptive strategy universal adaptive strategy

Introduction

CSR classification (Grime et al. 1988) method for the categorization of plant species (Grime's (1974, 1977, 2001) theoretical) competitor, stress tolerator and ruderal (CSR theory). The CSR classification is functional traits quantified in situ (or in situ collected in situ) and has been applied to species across Europe in a...

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A global method for calculating plant CSR ecological strategies applied across biomes world-wide

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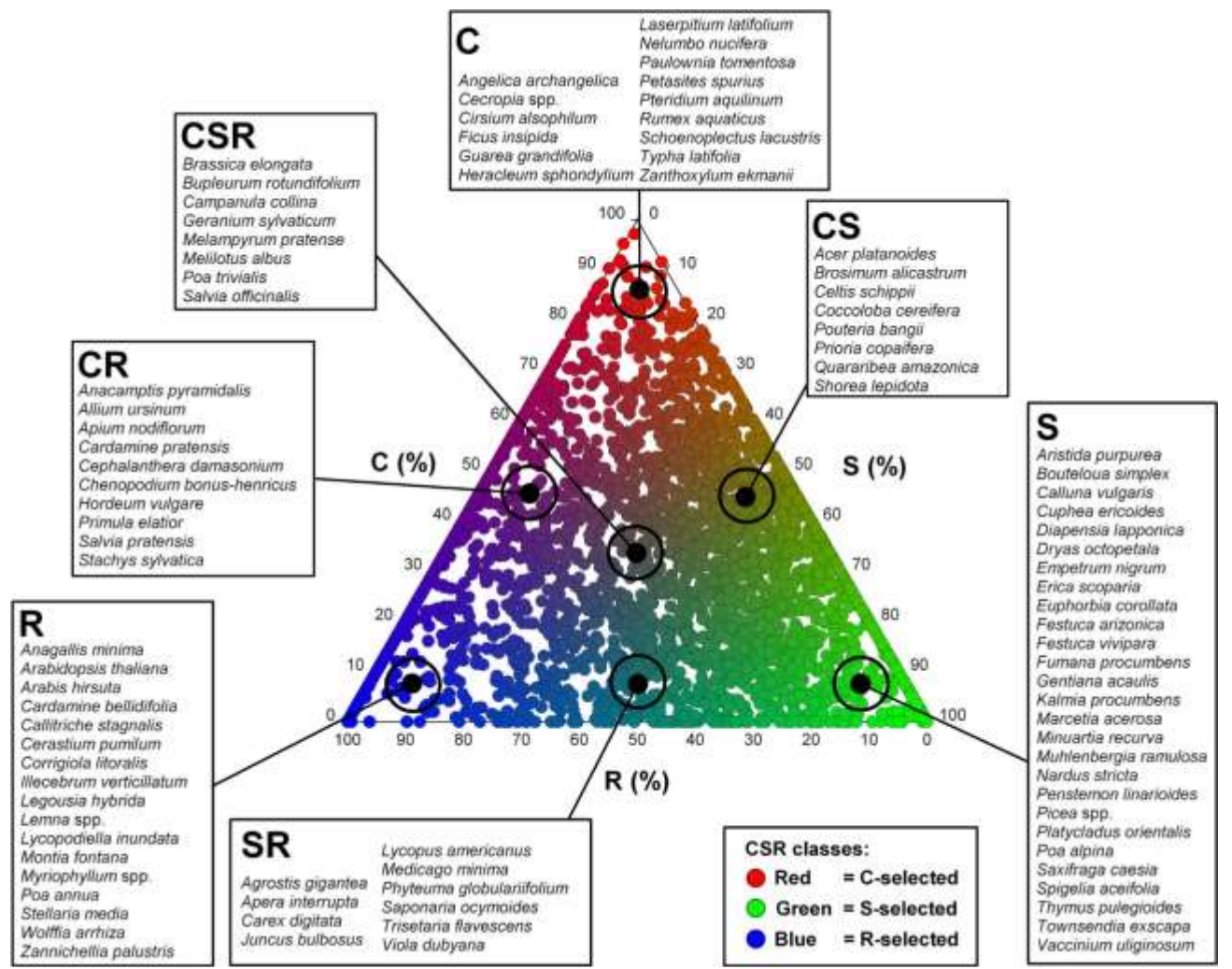


Fig. 3. Relative proportion (%) of C-, S- and R-selection for 3068 tracheophyte species measured from natural habitats across the world, using the globally calibrated CSR analysis tool 'StrateFy'. Species names represent examples of the seven secondary CSR strategy classes (C, CS, CR, CSR, S, SR and R) suggested by Grime (2001). (Figure from Pierce et al 2017)

Can Trait-Based Schemes Be Used to Select Species in Urban Forestry?

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Urban forests in northern Europe are threatened by climate change and biodiversity risks, and in response, city planners are urged to select a wider portfolio of tree species to mitigate the risks of species die-off. However, selecting the right species is a challenge, as most guidance available to specifiers focuses on ecosystem service delivery rather than the information most critical to tree establishment: the ability of a species to tolerate the stresses found in a given place. In this paper, we investigate the potential of using ecological techniques to describe ecological traits at the level of species selection, and the potential of functional ecology theories to identify species that are not widely discussed or specified at present but might be suitable. We collected trait data on 167 tree species across 37 genera, including 39 species within a case study genus, *Magnolia* L., and tested four theories that posit ways in which traits trade off against each other in predictable ways. We found that at this scale, most species recommended for urban forestry tend to be clustered along an axis of variation describing pace of life and stress tolerance, and that most *Magnolia* species are described as being fast-growing rather than stress-tolerant, although there is a degree of inter-specific variation. Further, we found that only one theory offers a succinct and reliable way of describing physiological strategies but translating ecological theory into a form appropriate for urban forestry will require further work.

Keywords: urban forestry, species selection, functional ecology, plant traits, ecological theories and techniques

INTRODUCTION

It is widely acknowledged that urban forestry's challenge of optimizing the fit between a tree and a site is likely to become increasingly difficult (Conroy and Marler Vocht, 2015; Espinosa-Balaguer et al., 2016; Matus Flores et al., 2019) as the rate and extent of global urban tree habitat decline is likely to be severe under climate change (Healey et al., 2020). To address this challenge, growing bodies of ecological and urban/landscape literature identify different causes and types of environmental stress (Clark and Buckley, 2020; Morrison et al., 2021), accompanied by an increasing understanding of the physiological responses to these different stresses (Mazzoni et al., 2014). However, a substantial gap exists between our understanding of these stress-response processes and the methods that urban foresters use to apply this knowledge when it comes to selecting species for urban environments. In this paper, we attempt to close this gap by exploring the potential of ecological trait-based theories to improve species selection in urban environments.

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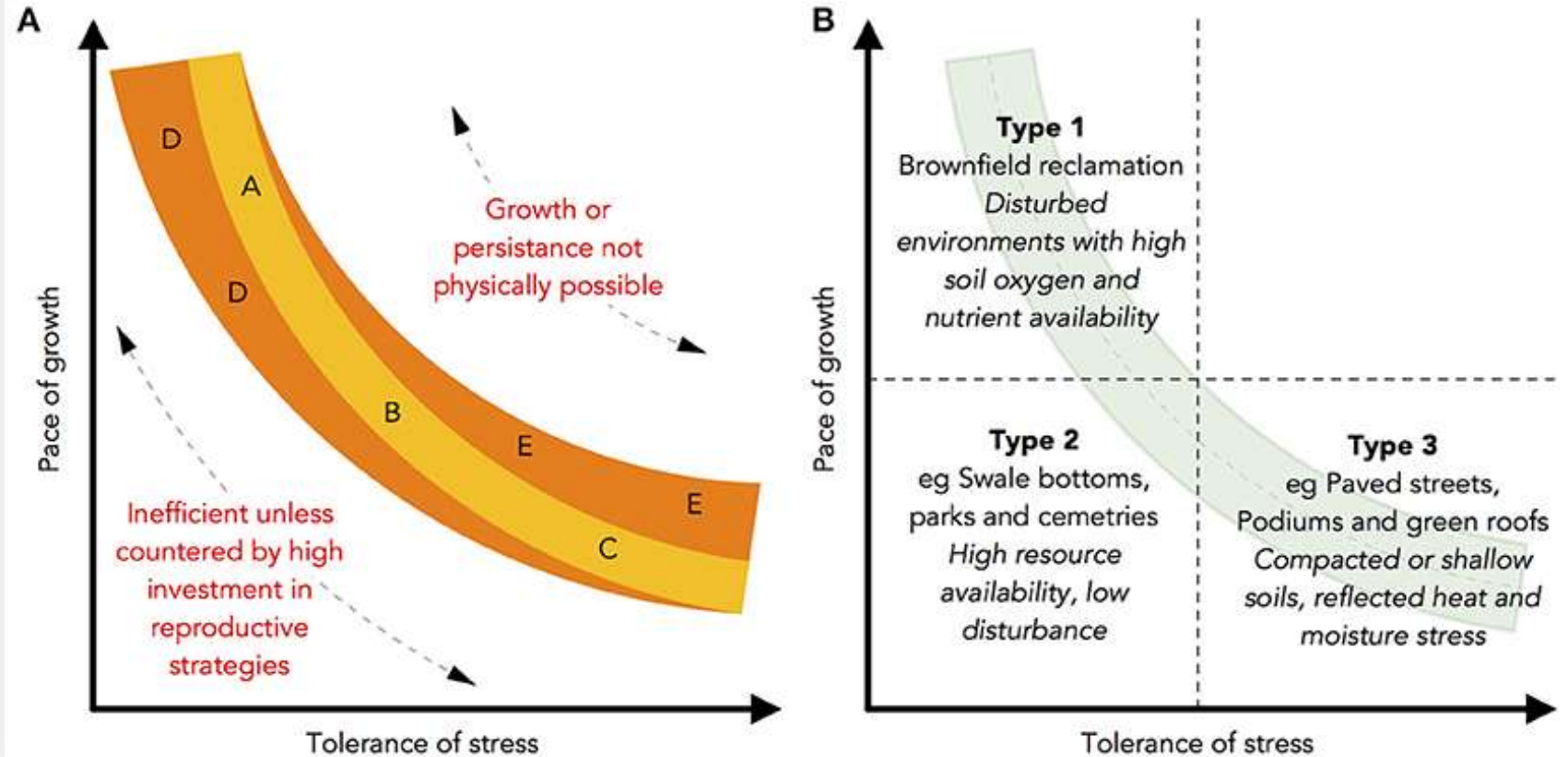


FIGURE 7 | (A,B) Hypothetical trait-based scheme for urban foresters. Building on CSR theory, (A) shows the variety of viable plant strategies in a trade-off between fast growth and high tolerance of stress. Positions A and C equate to different extremes of the trade-offs between competitive-stress tolerant strategies, with position B representing a generalist strategy. A greater investment in reproduction and faster growth is required in more ruderal environments, resulting in more ruderal strategies (D), whilst in more stressful situations, delayed sexual maturity allows for greater investment in dense structural and photosynthetic tissues (E). Note that unlike other similar graphs, the trait trade-off is fitted by a quadratic rather than linear line of best fit. (B) Overlays environments found in urban forests upon this model, resulting in a method for best fitting tree species to urban forestry sites.



Using the CSR Theory when Selecting Woody Plants for Urban Forests: Evaluation of 342 Trees and Shrubs

By Henrik Sjöman, Andrew Hiron, and Harry Watkins

Abstract. Background: The development of a framework for optimising plant selection, with the objective of integrating plant resilience for site and function, is crucial for urban forest managers and designers. The principal objective of this study was to evaluate the leaf economics spectrum of trees and shrubs and to categorise them using the CSR classification system, classifying plants according to 3 principal strategies (Competitors [C], Stress tolerators [S], Ruderal [R]), which represent a spectrum of plant forms and functions arising under conditions of competition, abiotic restriction to growth, or periodic disturbance, respectively. The second objective was to discuss how the CSR classification system applied plant ecological strategies to plant specification in urban environments. Methods: The method for ordinating species in CSR space is based on leaf economic data including Leaf Area, Leaf Dry Matter Content, and Specific Leaf Area. Data were assembled at the Swedish University of Agricultural Sciences Campus Arboretum. Results: A total of 342 taxa (170 tree and 172 shrubs) were examined in this study. The study taxa were distributed along the Competitor-Stress tolerator (CS) axis of the ternary plots. The data analysis indicated that shrubs exhibited a more expansive position in the model, displaying a greater prevalence of stress tolerators and species with a more comprehensive approach to disturbance, competition, and stress compared to trees. Conclusion: The results provided an understanding and rationale for how species-specific selection for urban environments could be carried out. This was based on trait-oriented plant selection using the CSR classification, which was then adapted to different urban situations and functions. As a result, not only can quadratic equations be derived which describe the distribution of shrubs and trees of evolutionary variation, but also the uses of tree and shrub species in urban environments can be quantitatively described.

Keywords. Climate Change; Diversity; Plant Selection; Urban Environments.

INTRODUCTION

Trees and shrubs provide distinctive combinations of ecosystem services (ES) in urban settings. Recent projections suggest that an overreliance on a limited range of species may compromise the ES provided by urban forests (Pauleit et al. 2017). The suboptimal fitness of plants for their climate and the diminished performance of their ES are frequently compounded by the planting of species in locations that are not conducive to their growth and development. In the planning and design of urban green infrastructure, it is of the utmost importance to be able to anticipate the development of different species under a variety of growing conditions. This enables the planning and anticipation of their needs for establishment and long-term maintenance, as well as their long-term

development in response to current and future climates. In a changing climate, characterised by increasingly hotter and periodically drier conditions, coupled with the densification of urban structures and the occurrence of severe outbreaks of diseases and pests, there are increasingly challenging conditions for the successful utilisation of plants (Koeser et al. 2014; Allen et al. 2015; Matusick et al. 2018; Yi et al. 2022). This is leading to a high proportion of trees and other plants dying or experiencing impaired development and establishment. (Kimmehr et al. 2024). In addition to the aforementioned factors, the natural mortality of trees in urban environments due to the aging of the urban tree population represents another significant cause of urban canopy loss (Roman et al. 2014). It is therefore crucial to gain a

Method

- Measure leaf area (LA), leaf fresh weight (LFW) and leaf dry weight (LDW)

- LA
- LDMC
- SLA
- C : S : R

A global method for calculating plant CSR ecological strategies applied across biomes world-wide

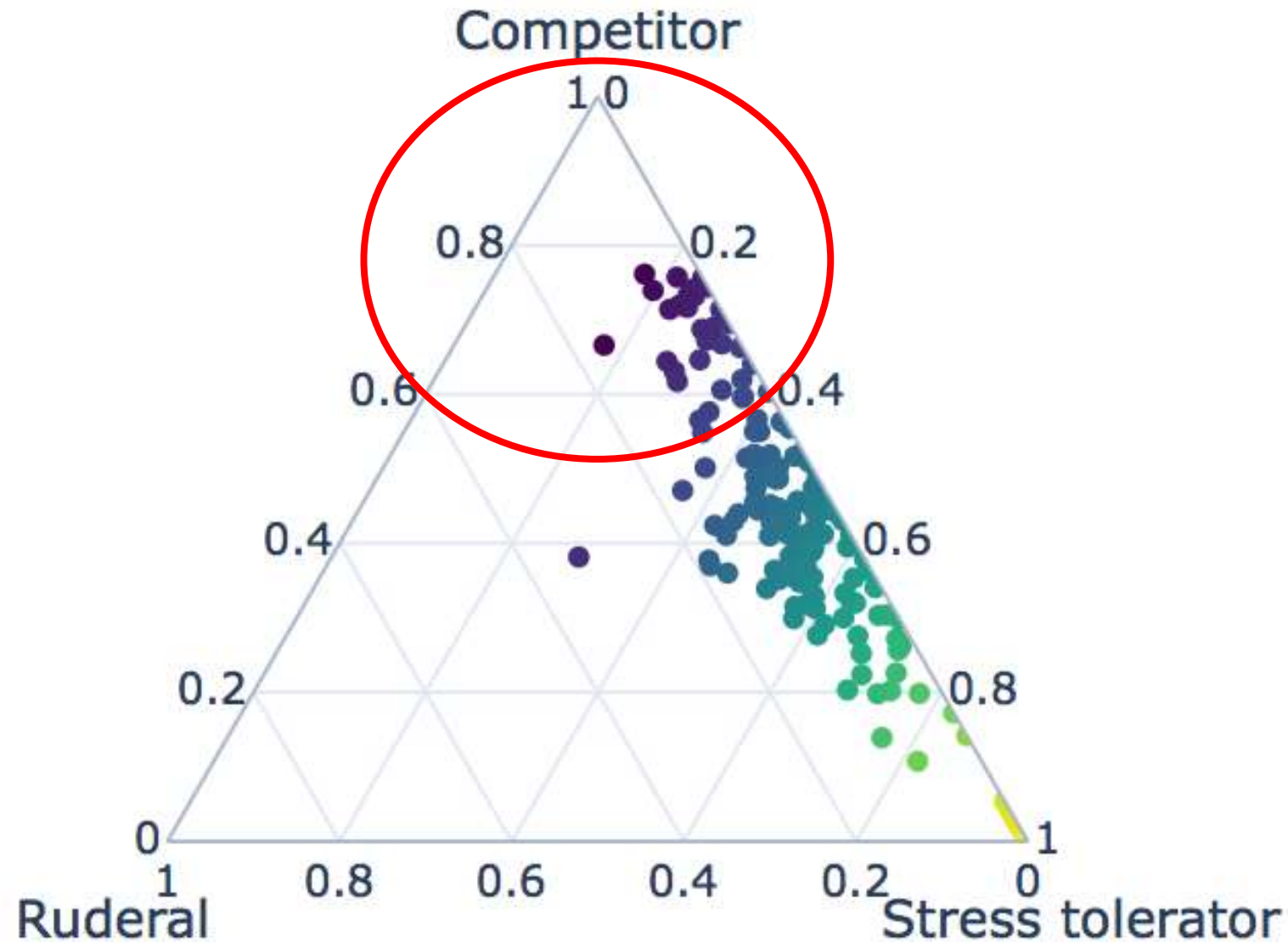
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Correction added after online publication on 6 November 2016: author name Oriado Wilson Fernandes corrected to Geraldo Wilson Fernandes.

HOW TO StrateFy: Either measure leaf traits (LA, LFW and LDW) and input these into columns D-F, or cut and paste LA, LDMC and SLA data directly into columns J-L. Paste or input your species names and info in these columns (A, B, C)			data input			calculated traits			traits for CSR analysis			CSR analysis output				
species binomial	family	notes	LA leaf area (mm ²) [single-sided leaf area with petiole]	LFW leaf fresh weight (mg) [saturated, turgid fresh weight]	LDW leaf dry weight (mg) [after oven drying to constant weight]	LSI leaf succulence index (% of fresh weight)	LWC leaf water content (% of fresh weight)	LMA leaf mass per area (g m ⁻²)	LA leaf area (mm ²)	LDMC leaf dry matter content (%)	SLA specific leaf area (mm ² mg ⁻¹)	C (%)	S (%)	R (%)	C : S : R =	Strategy class
Mean trait values:			369615.7	84009.6	21187.8	1.7	74.8	57.3	369615.7	25.2	17.4	83.6	9.9	6.5	84 : 10 : 7 %	C
Mean trait values:			11.8	4.5	1.8	2.3	60.3	151.8	11.8	39.7	6.6	0.0	100.0	0.0	0 : 100 : 0 %	S
Mean trait values:			55.7	12.3	1.6	1.9	86.7	29.4	55.7	13.3	34.1	4.3	0.0	95.7	4 : 0 : 96 %	R
Replicate 1 values:			36061.2	6988.0	2480.0	1.3	64.5	68.8	36061.2	35.5	14.5	67.6	25.9	6.5	68 : 26 : 6 %	C/CS
Replicate 2 values:			22391.8	8292.0	2756.0	2.5	66.8	129.1	22391.8	33.2	8.1	69.1	30.9	0.0	69 : 31 : 0 %	C/CS
Replicate 3 values:			30068.1	6868.0	2476.0	1.5	83.9	82.3	30068.1	36.1	12.1	67.2	28.9	3.9	67 : 29 : 4 %	C/CS
Replicate 4 values:			31059.5	9356.0	3292.0	2.0	64.8	106.0	31059.5	35.2	9.4	71.0	29.0	0.0	71 : 29 : 0 %	C/CS
Calculation of mean:			29895.1	7876.0	2751.0	1.7	65.1	92.0	29895.1	34.9	10.9	69.3	28.7	2.0	69 : 29 : 2 %	C/CS

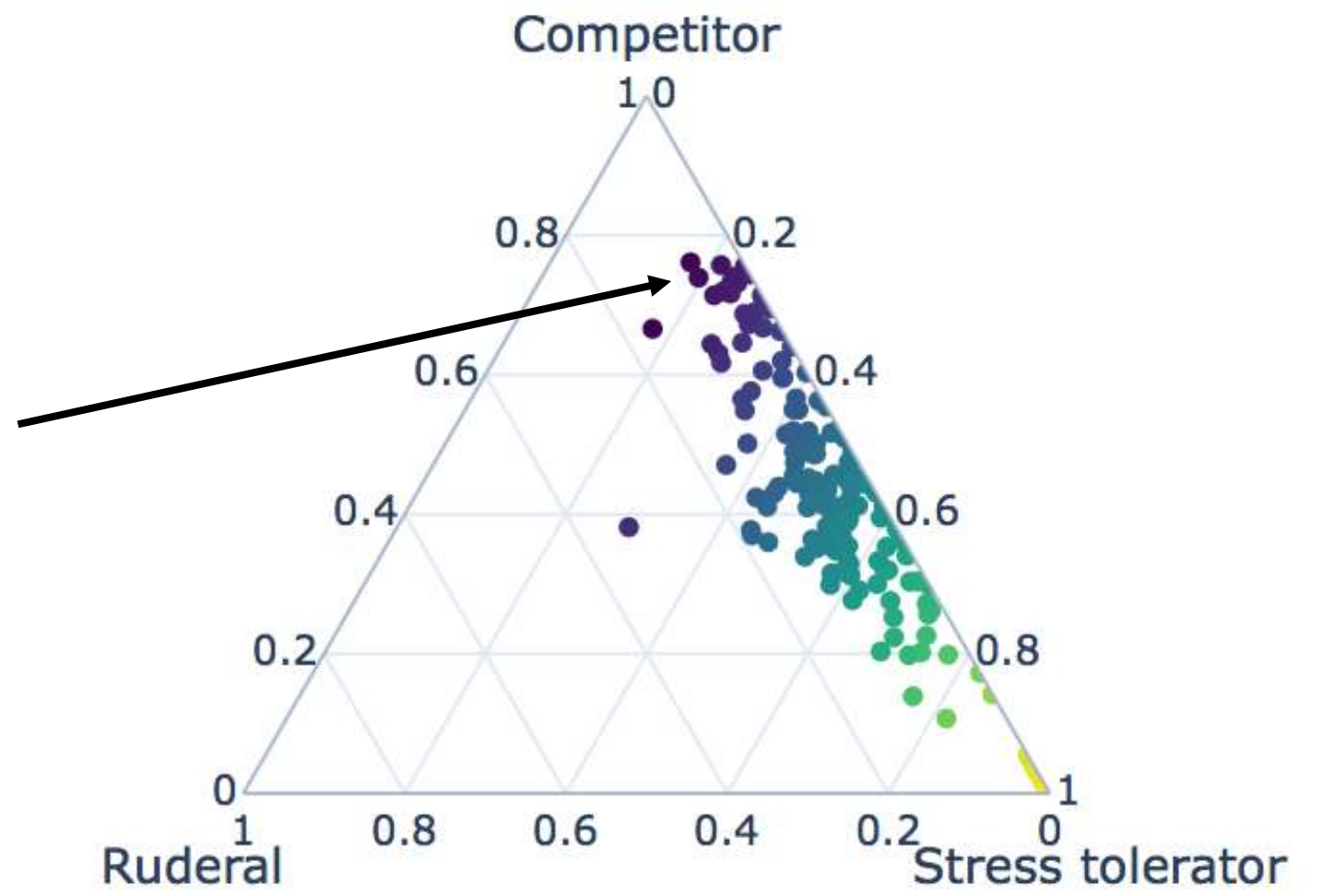
CSR ordination of species growing in Alnarp arboretum



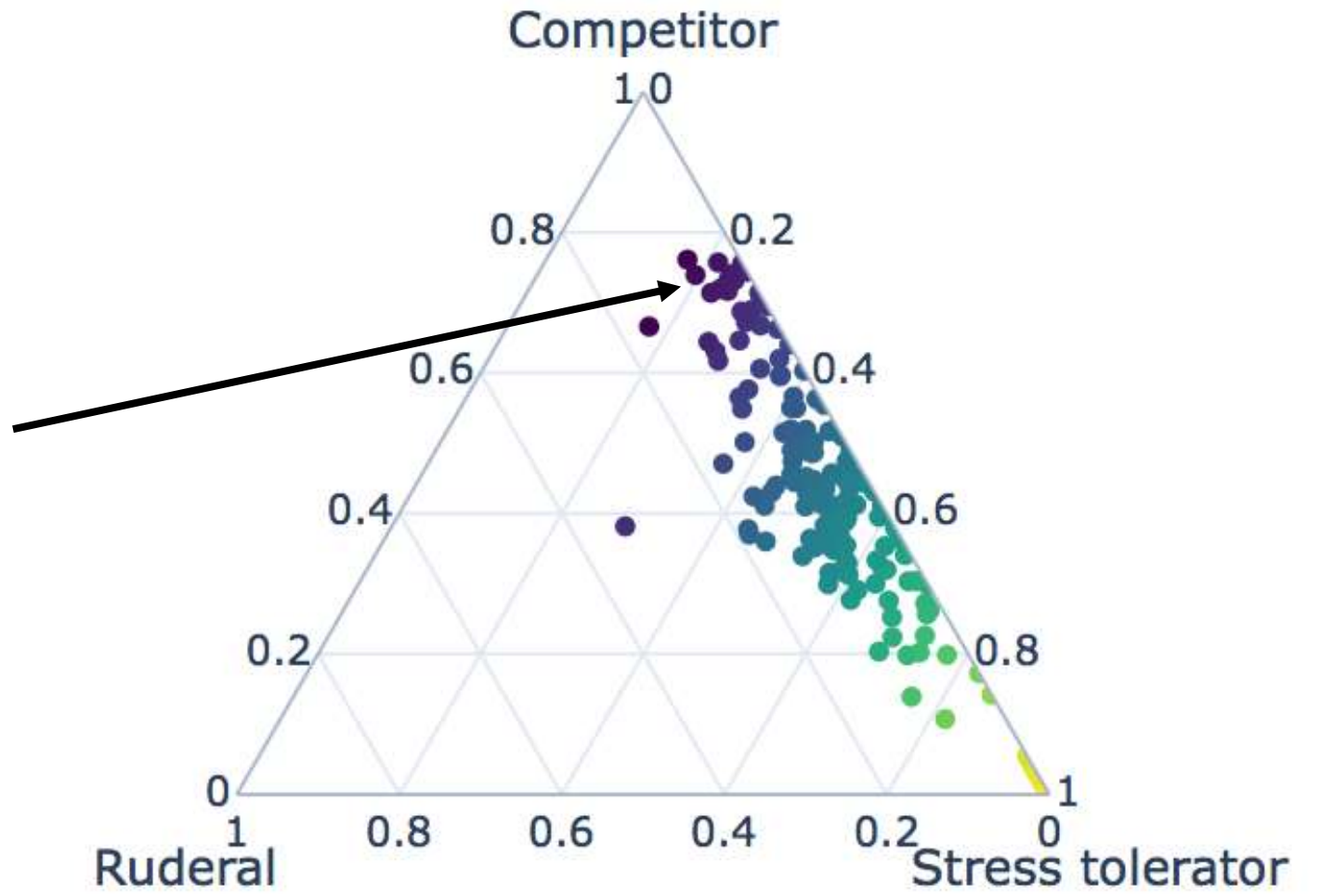
Acer saccharinum



Populus sp.

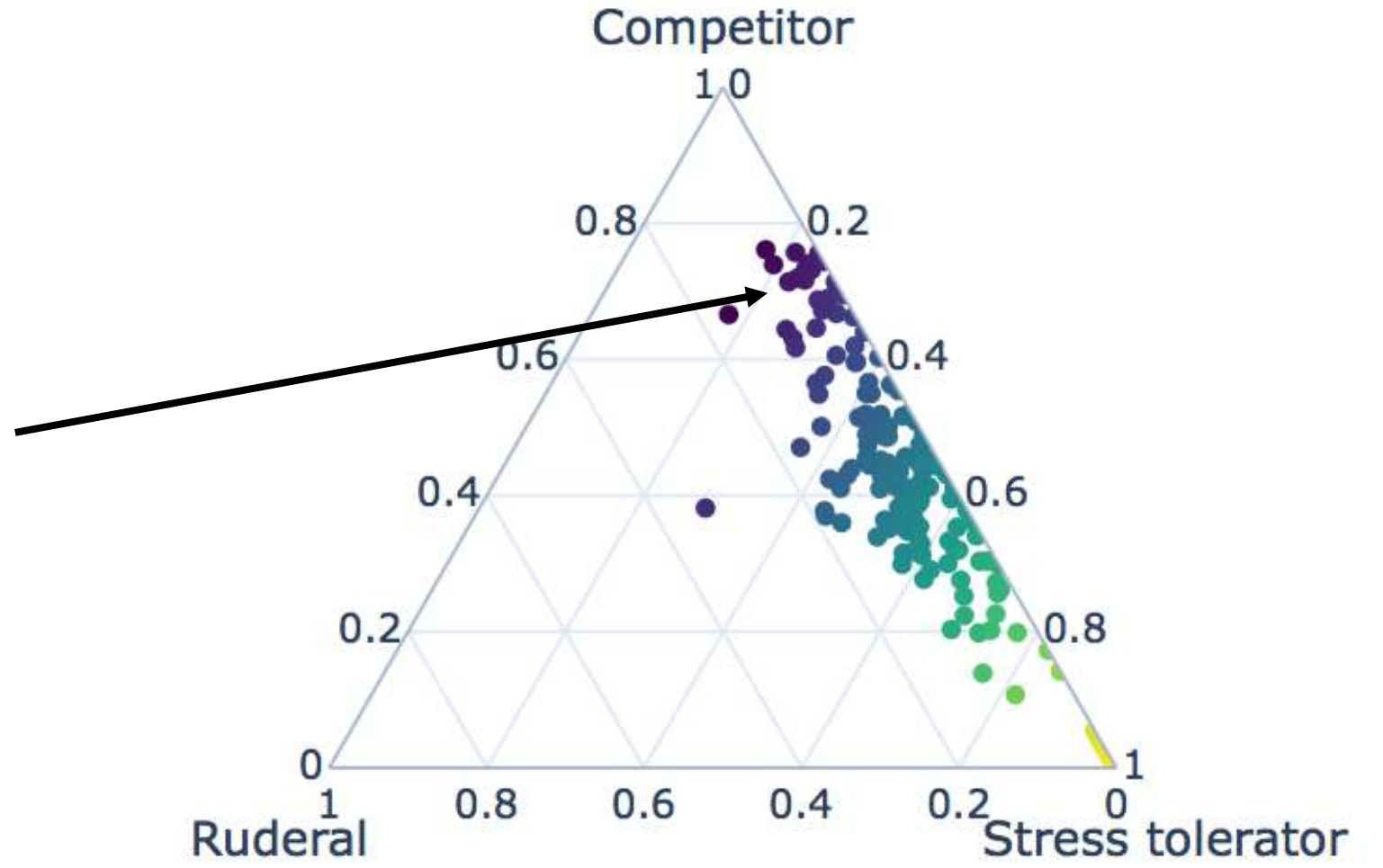


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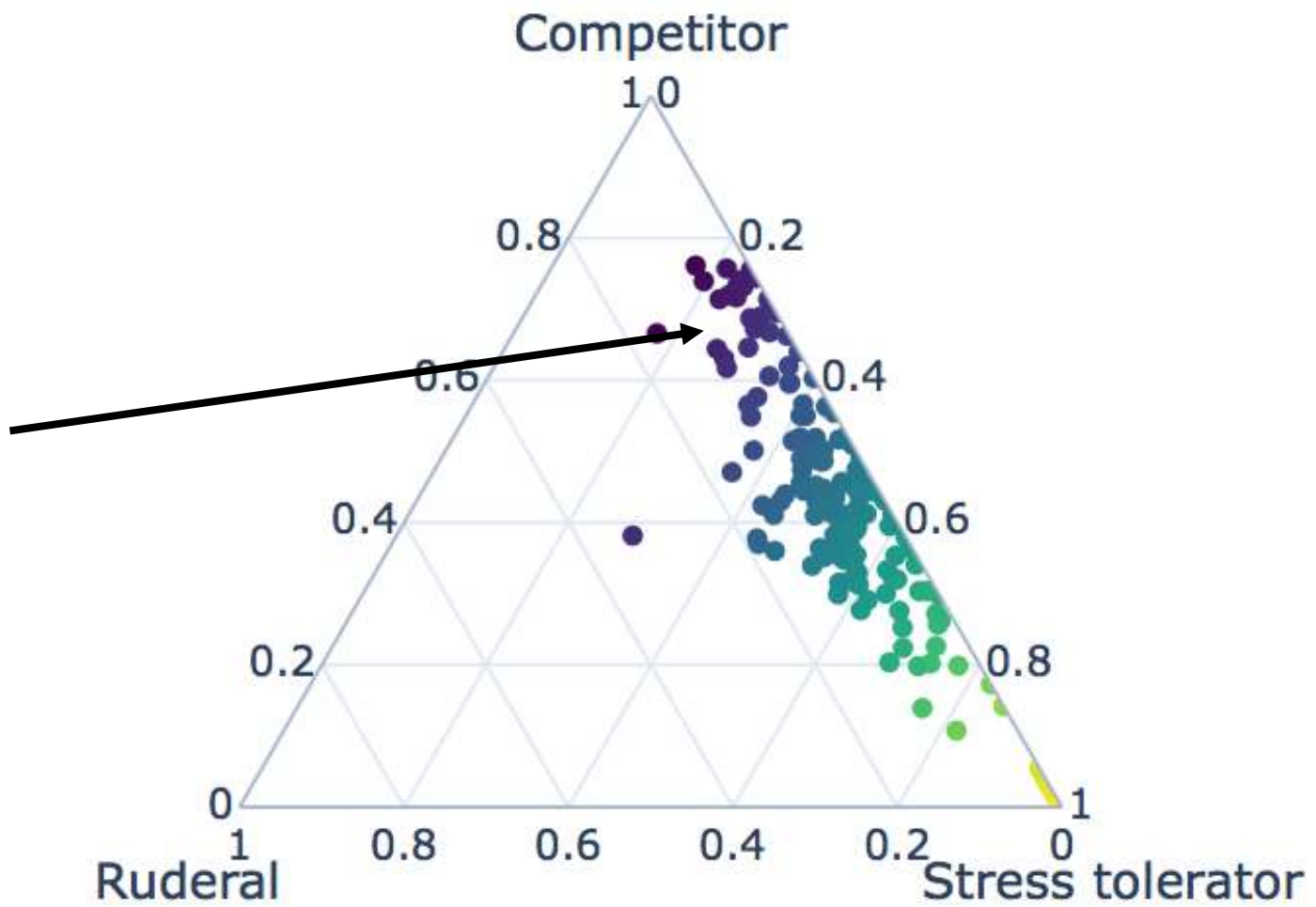


(Sjöman, Hirons and Watkins, 2025)

Magnolia obovata

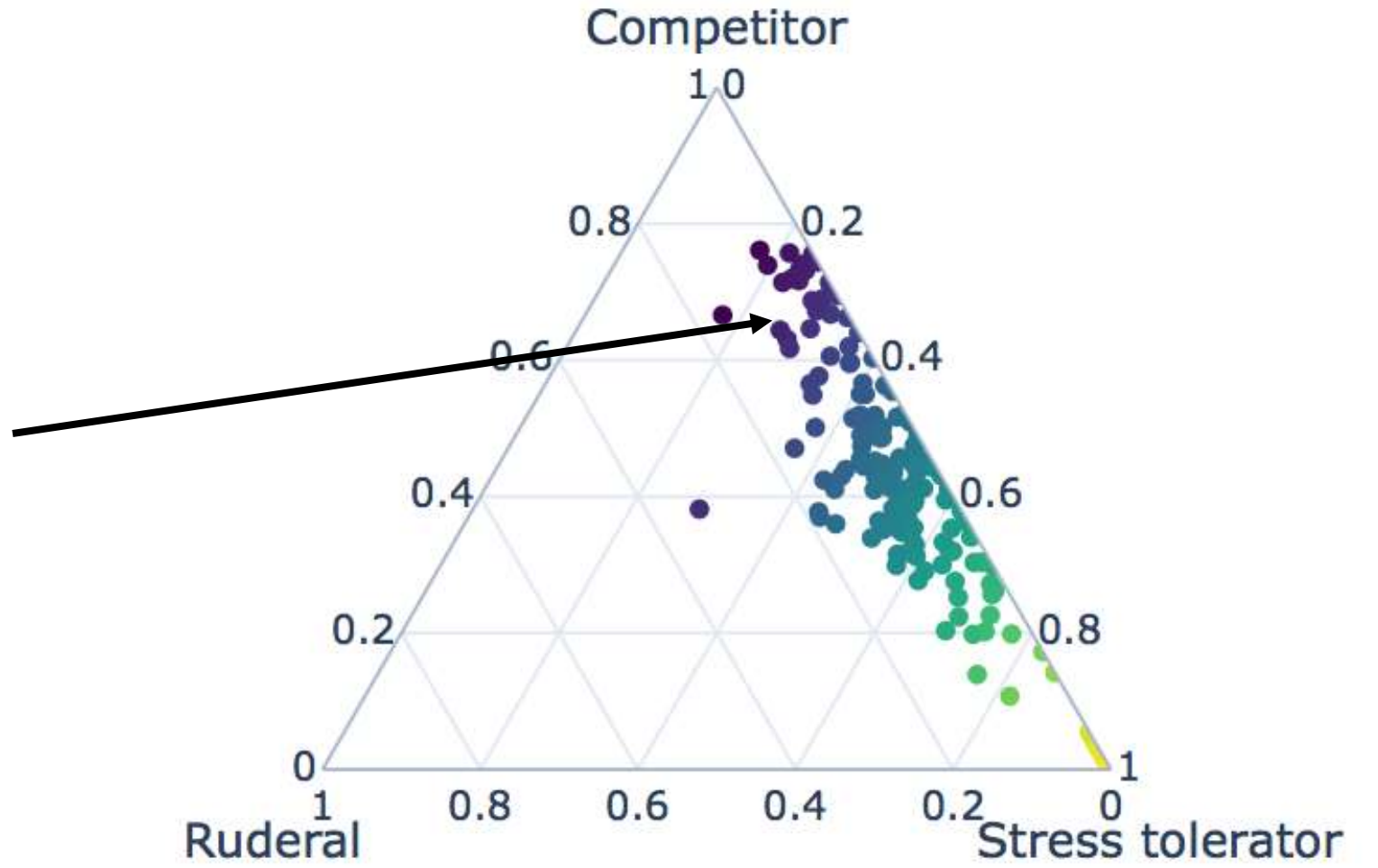


(Sjöman, Hiron and Watkins, 2025)



(Sjöman, Hirons and Watkins, 2025)

Acer pseudoplatanus

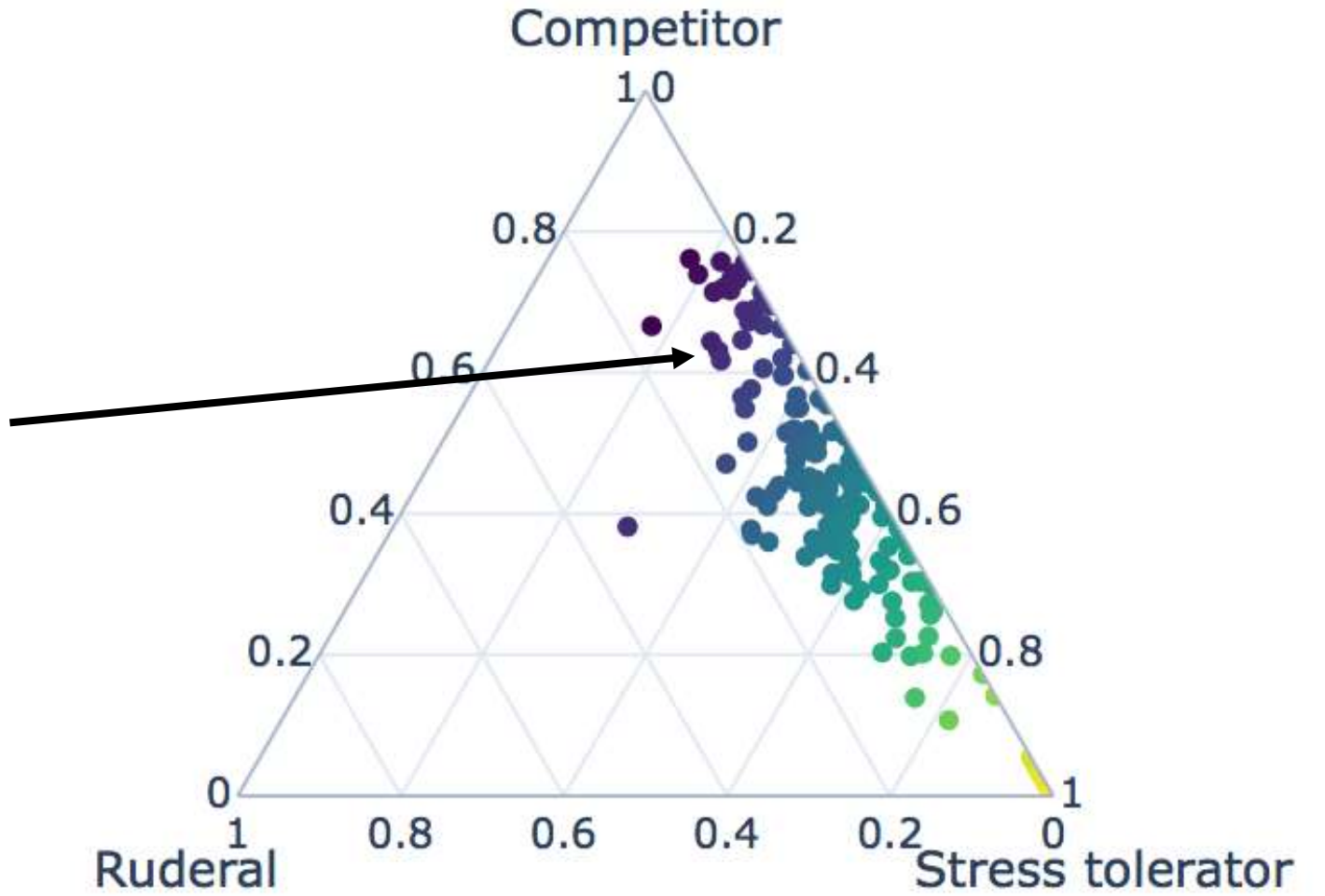


(Sjöman, Hiron and Watkins, 2025)

Liriodendron tulipifera

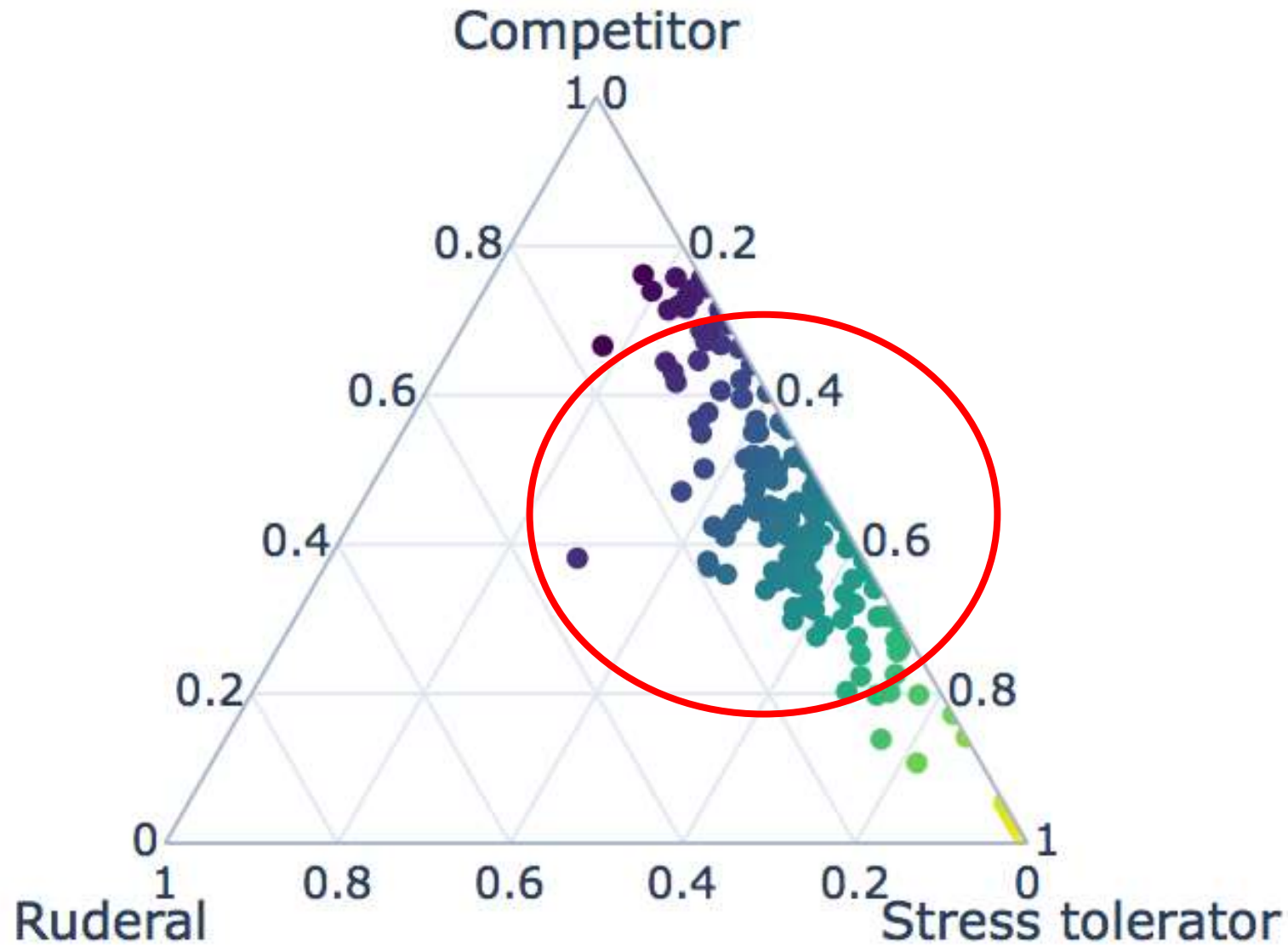


Cladastris kentukea



(Sjöman, Hirons and Watkins, 2025)

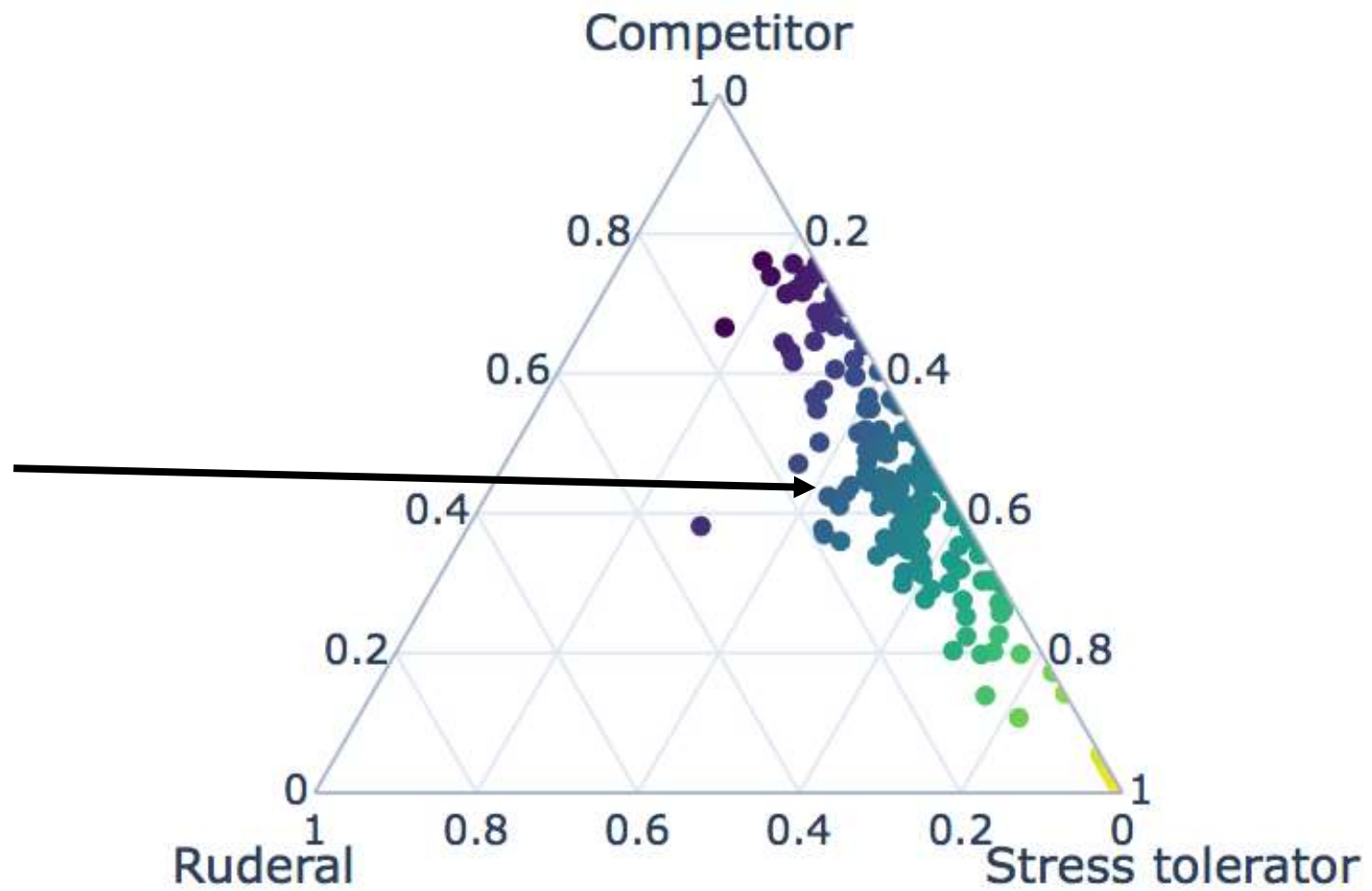
CSR ordination of species growing in Alnarp arboretum



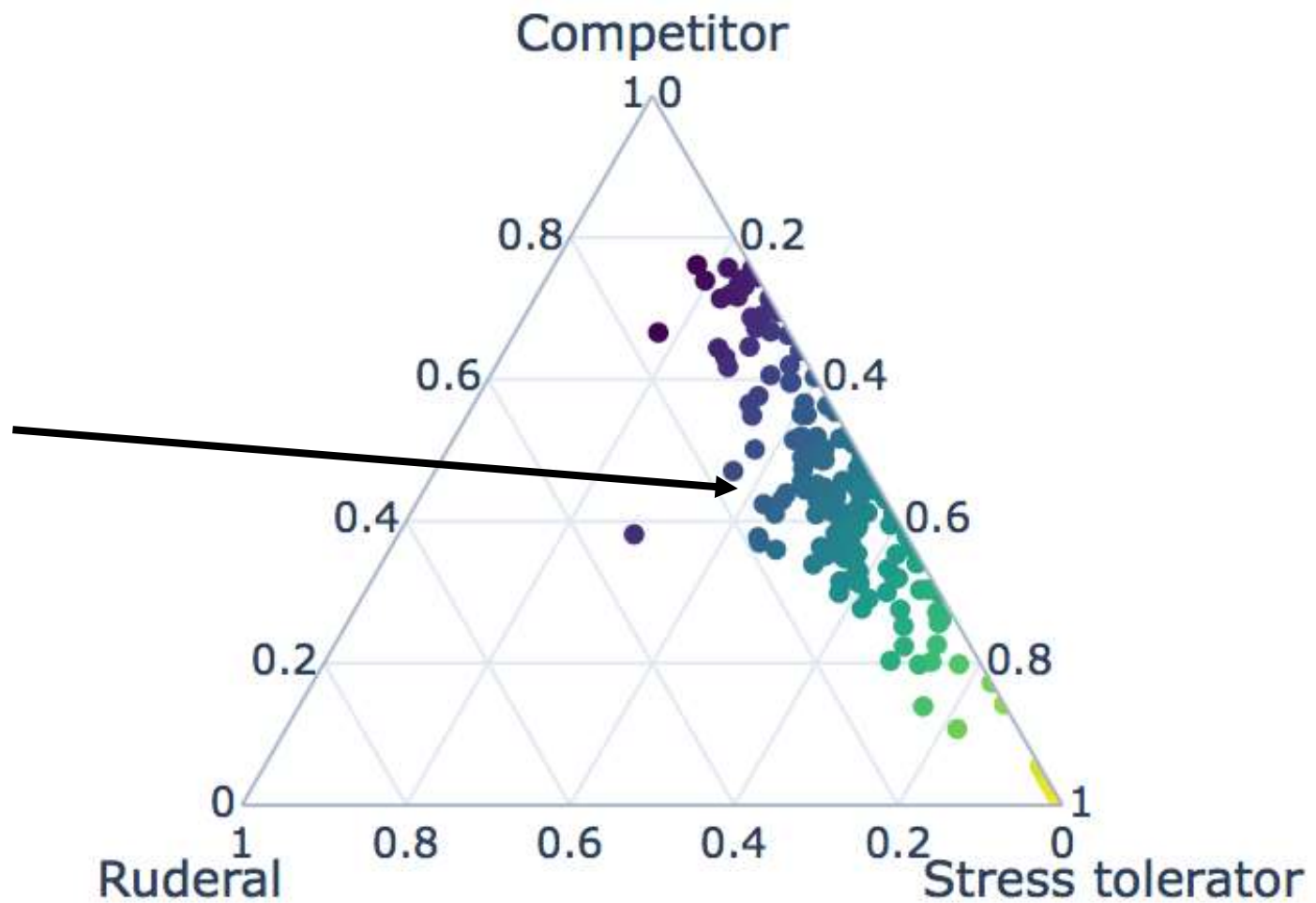
(Sjöman, Hiron and Watkins, 2025)



Corylus colurna



(Sjöman, Hiron and Watkins, 2025)

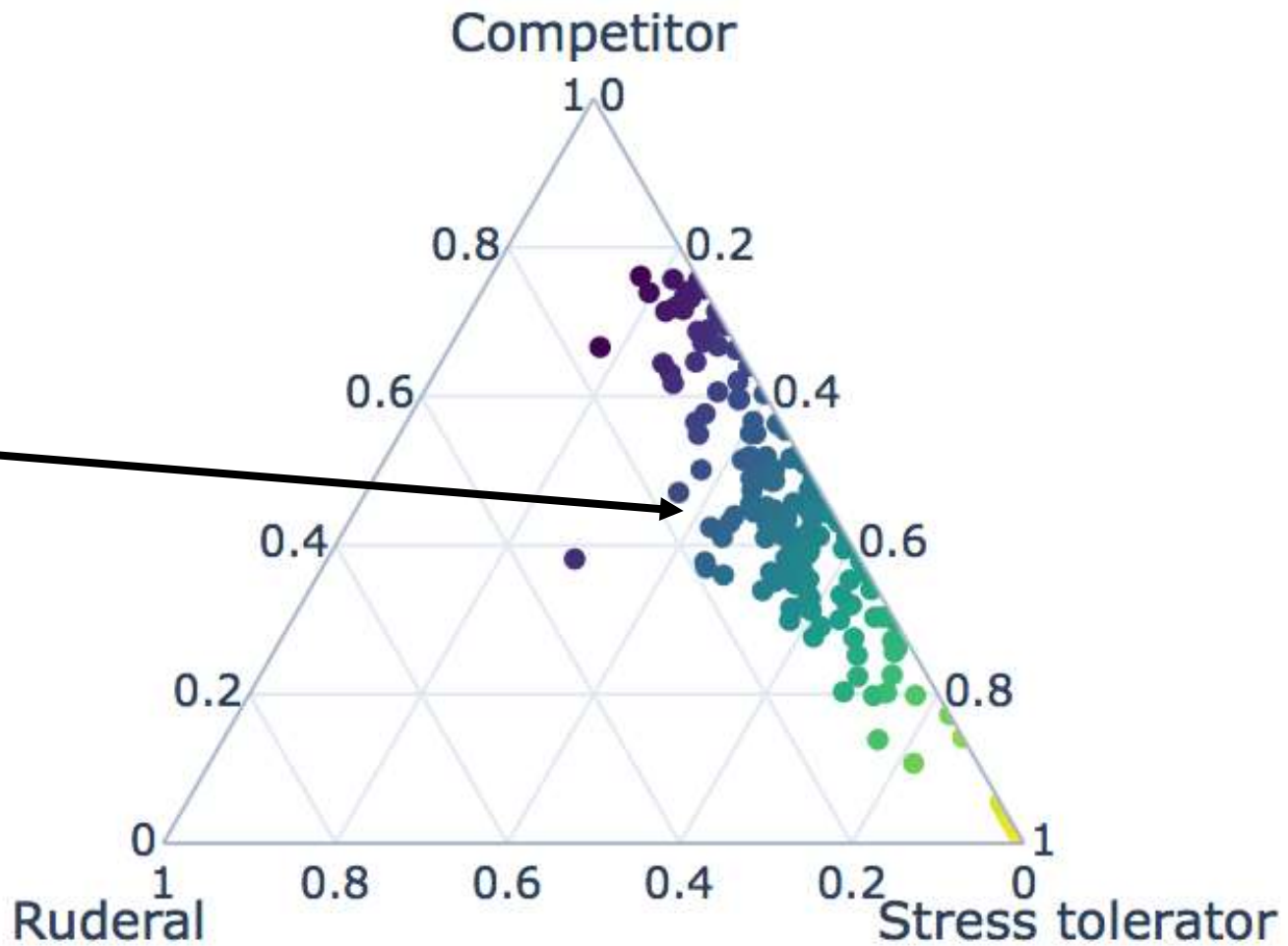


(Sjöman, Hirons and Watkins, 2025)

Acer campestre

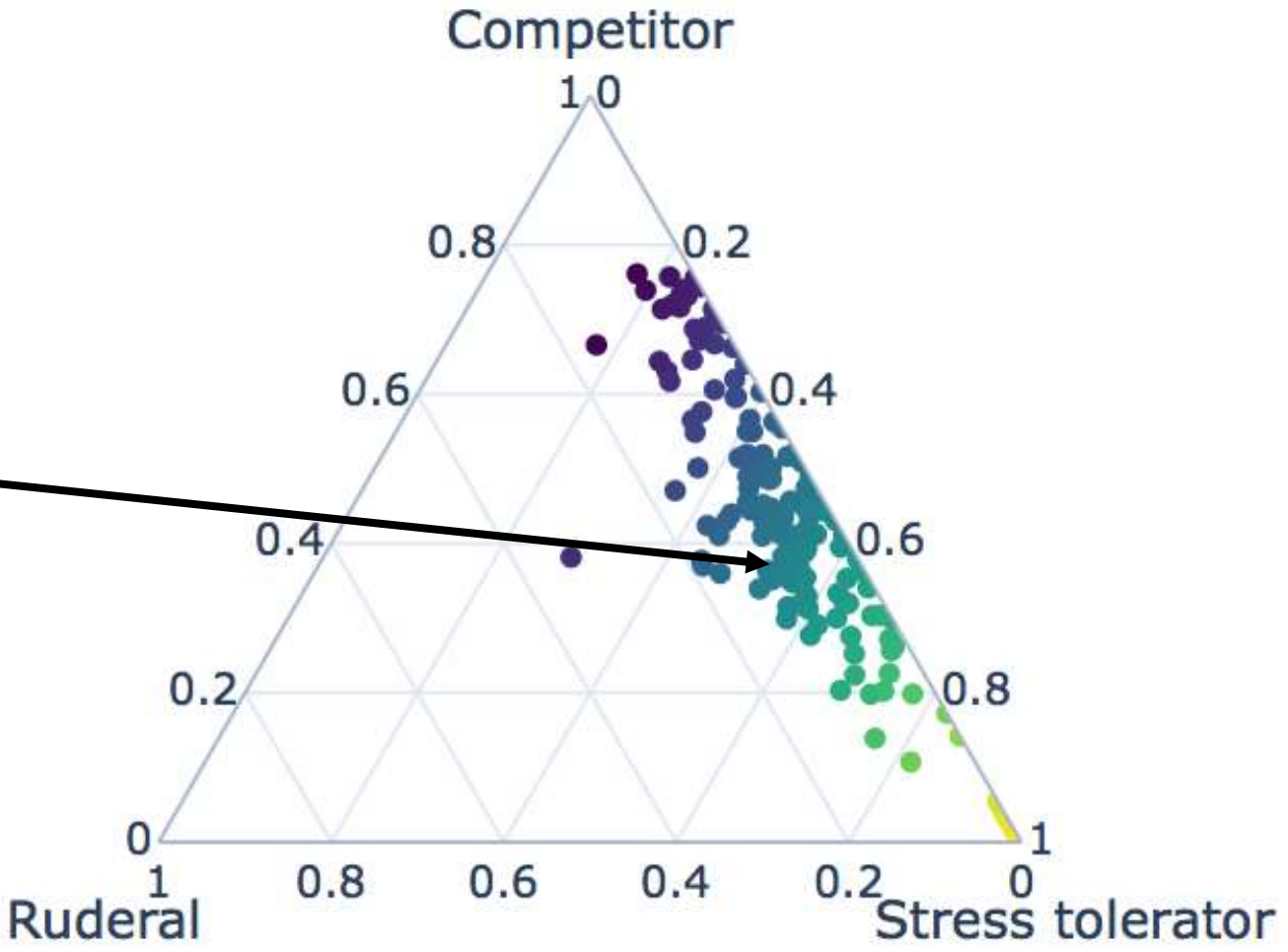


Sorbus intermedia



(Sjöman, Hiron and Watkins, 2025)

Tilia tomentosa

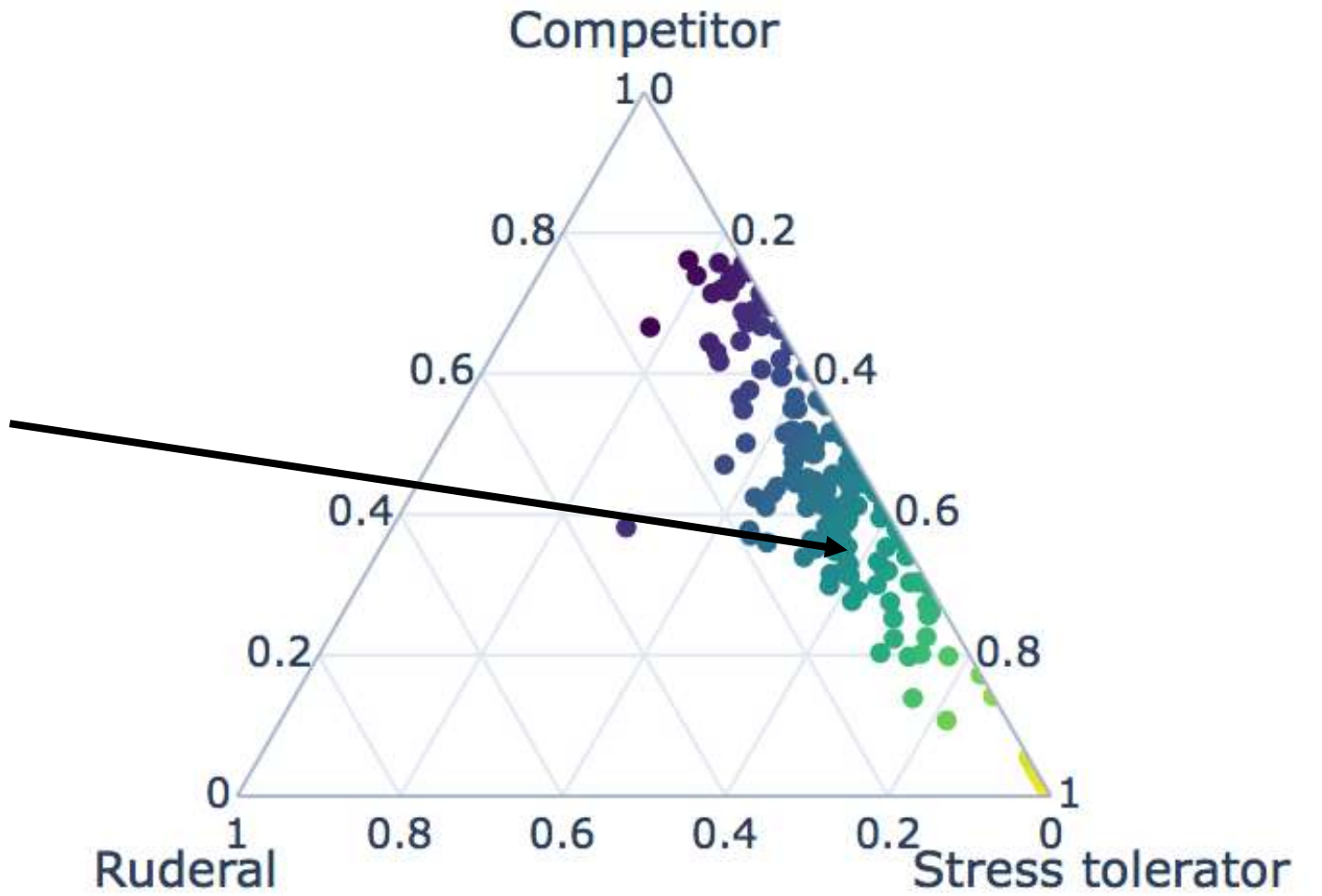


(Sjöman, Hiron and Watkins, 2025)

Acer x zoeschense

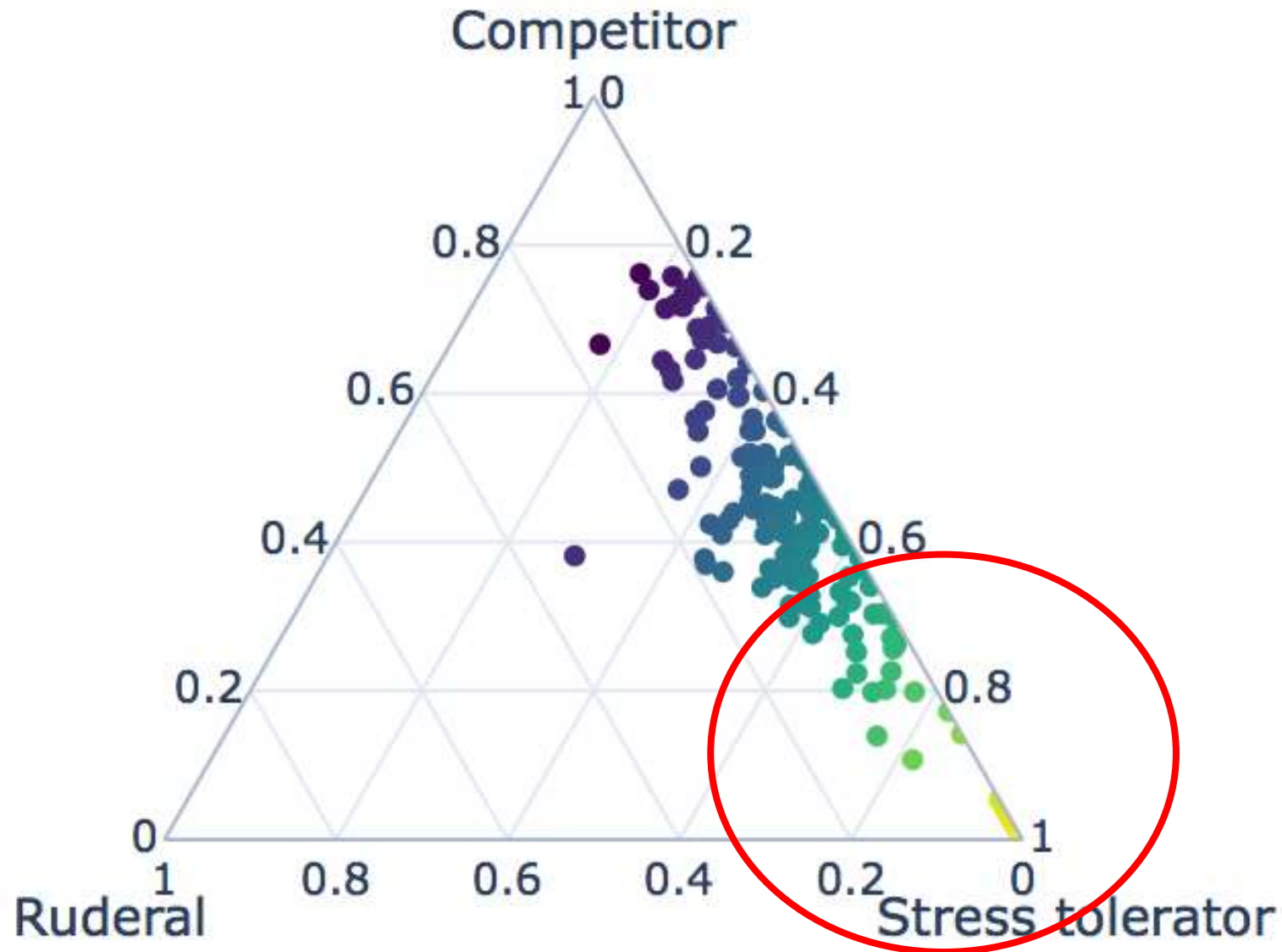


Metasequoia glyptostroboides

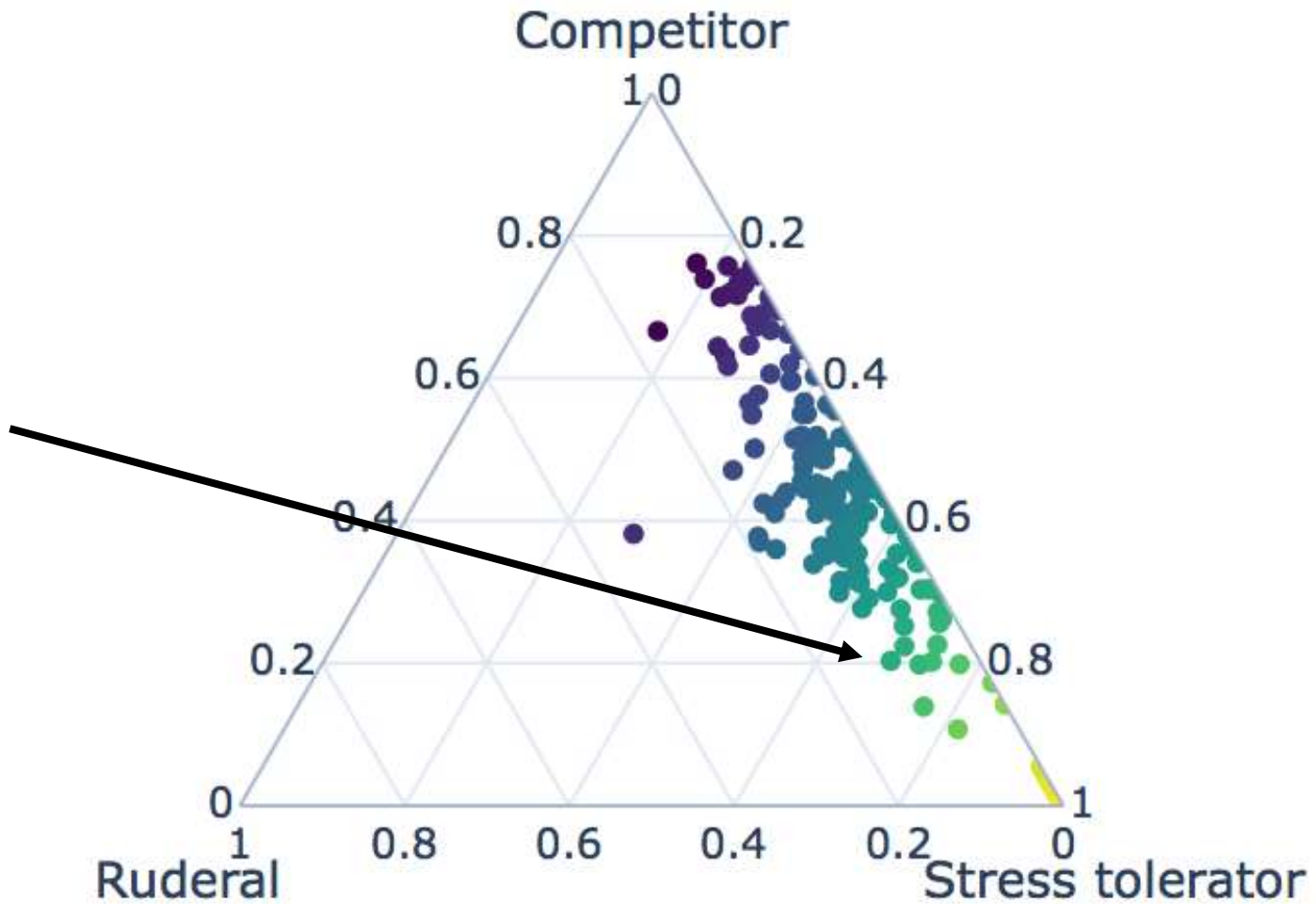


(Sjöman, Hiron and Watkins, 2025)

CSR ordination of species growing in Alnarp arboretum



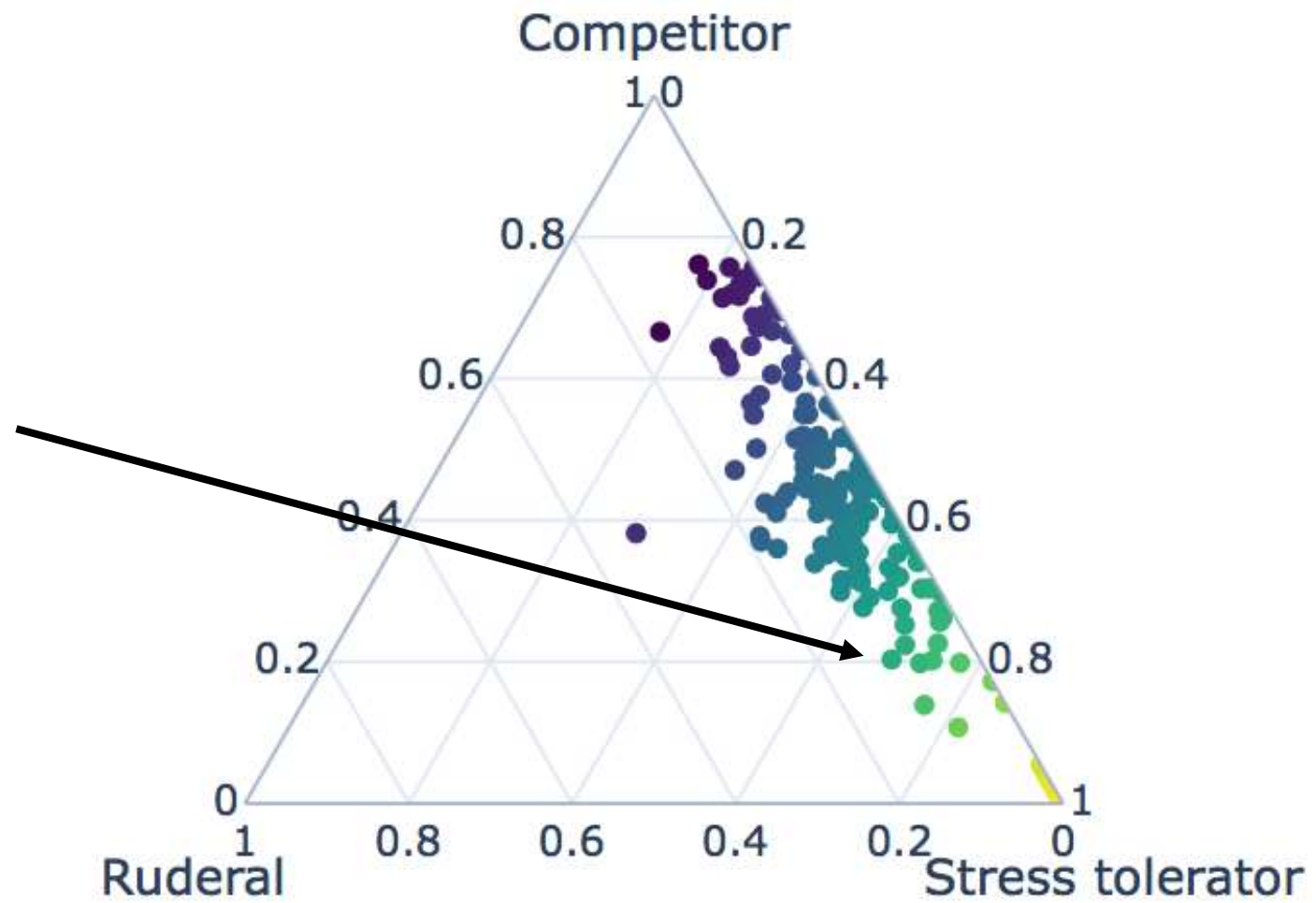
(Sjöman, Hiron and Watkins, 2025)



(Sjöman, Hirons and Watkins, 2025)



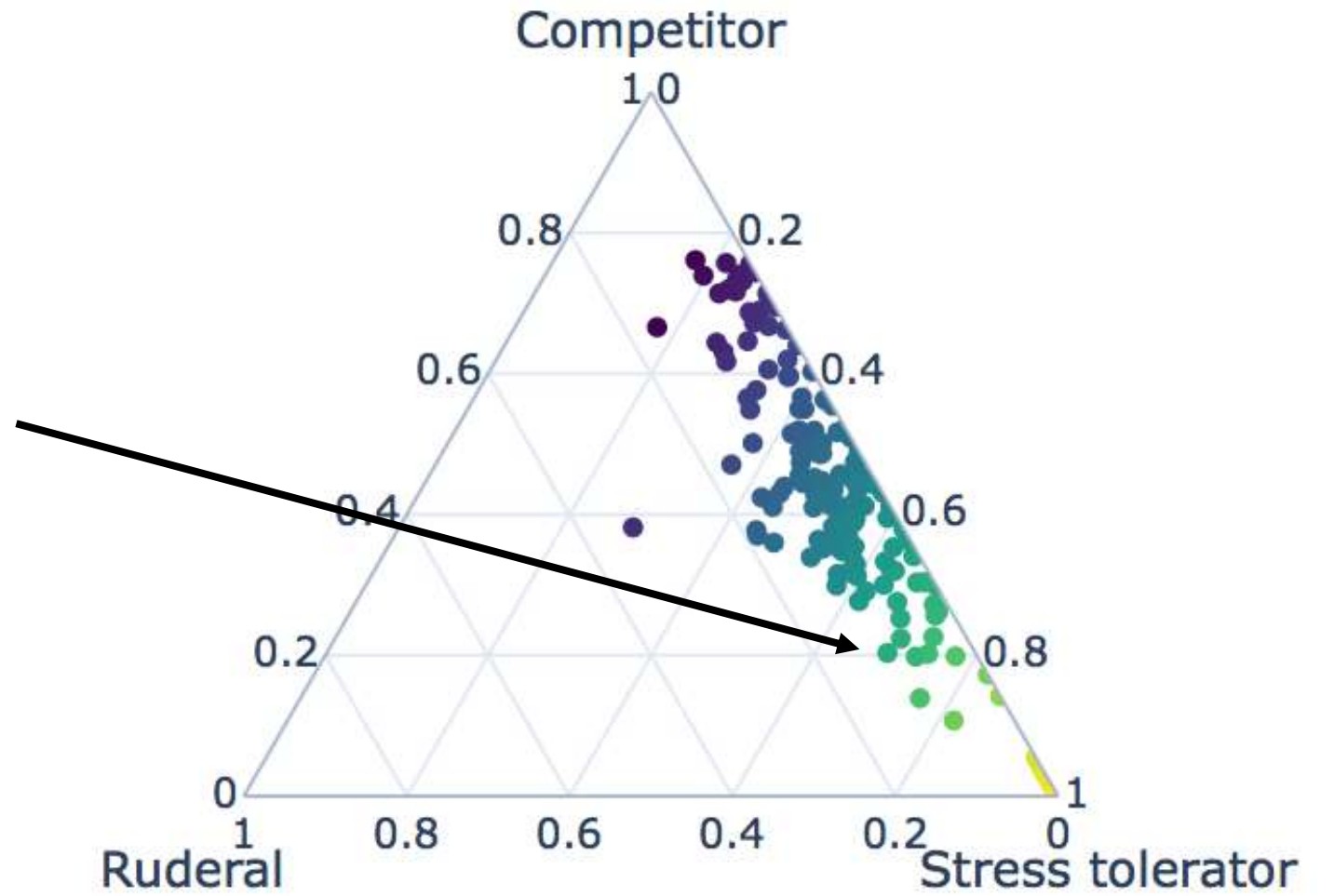
Syringa reticulata



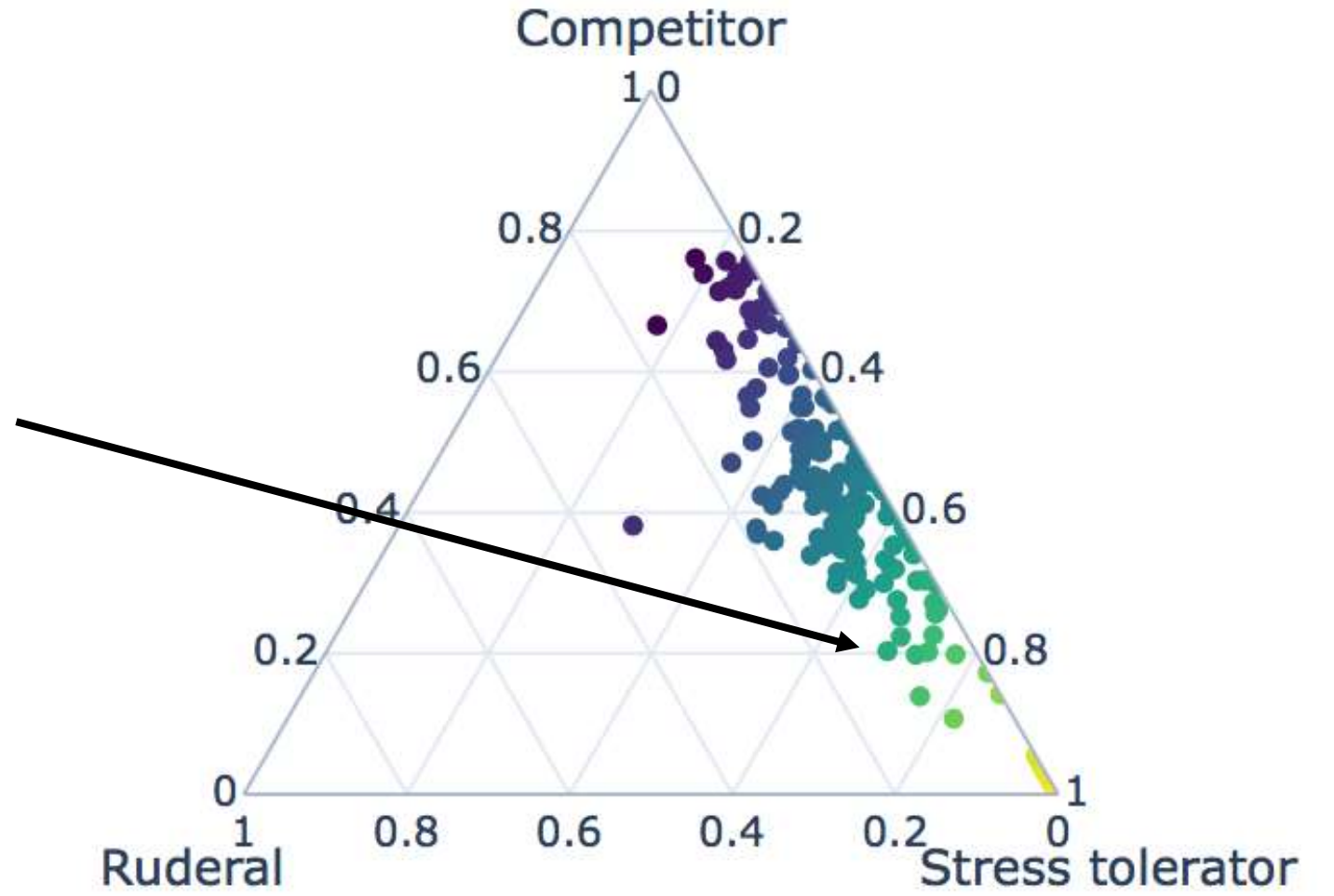
(Sjöman, Hiron and Watkins, 2025)



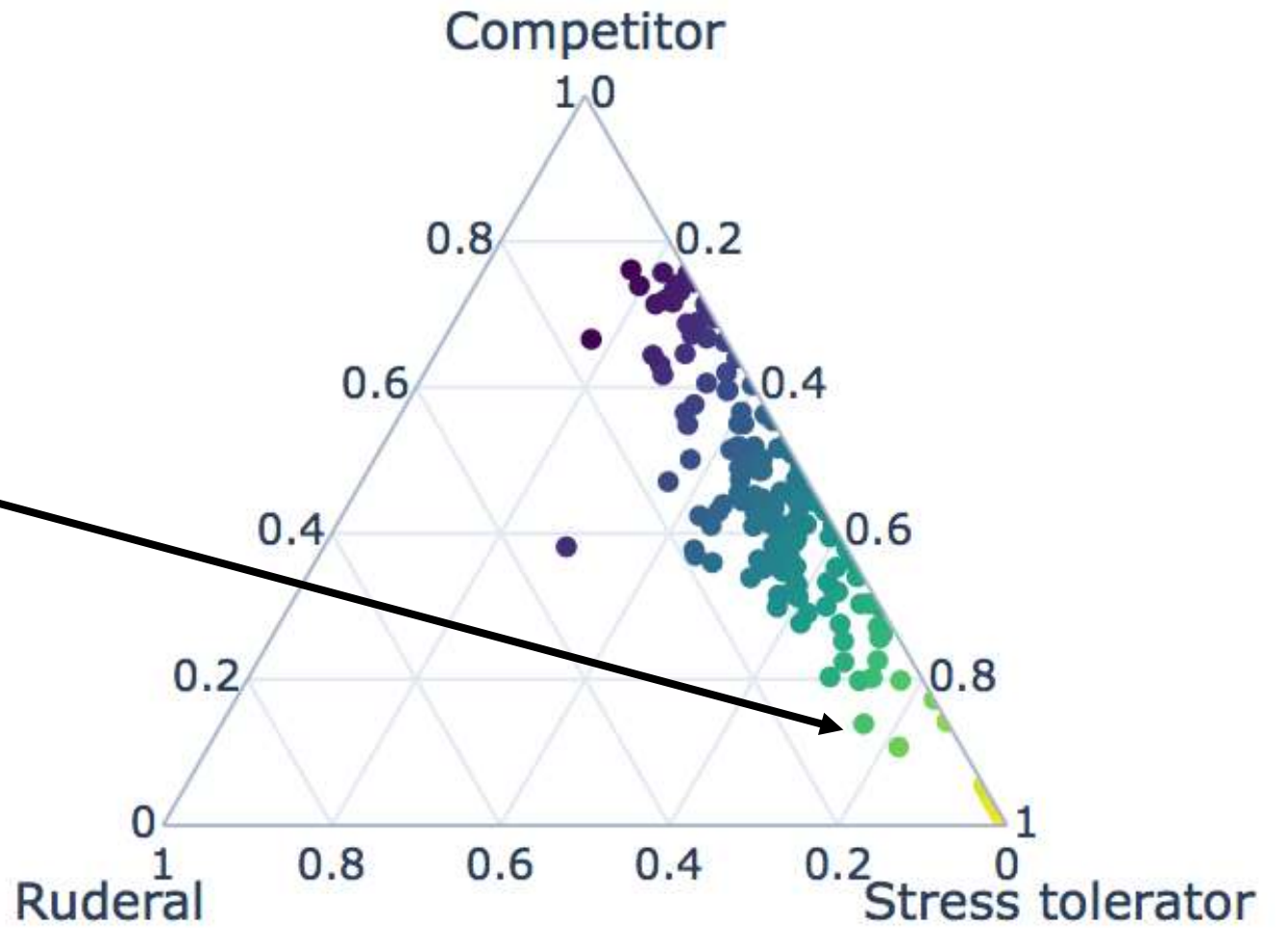
Koelreuteria paniculata



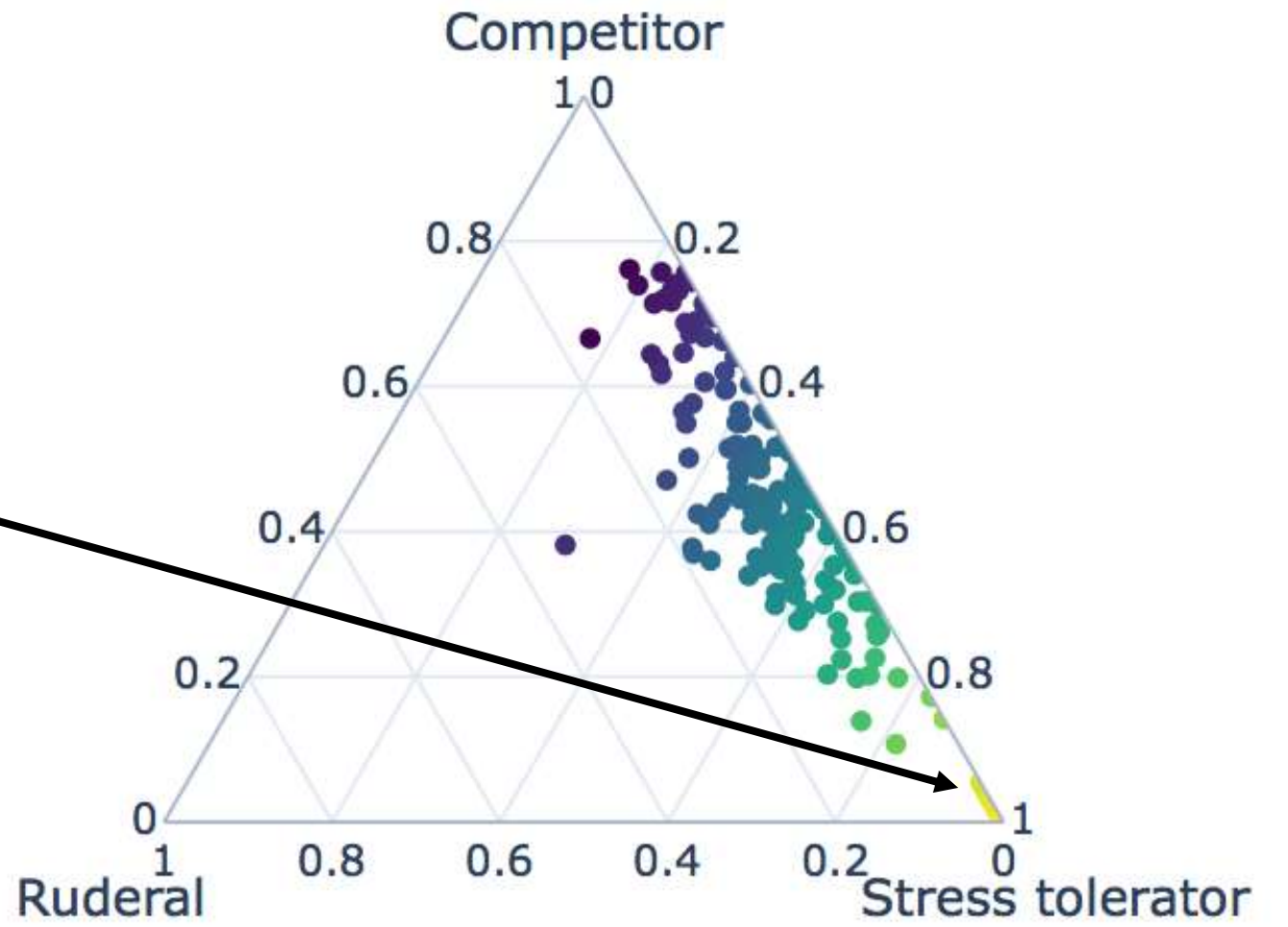
(Sjöman, Hiron and Watkins, 2025)



(Sjöman, Hiron and Watkins, 2025)



(Sjöman, Hiron and Watkins, 2025)

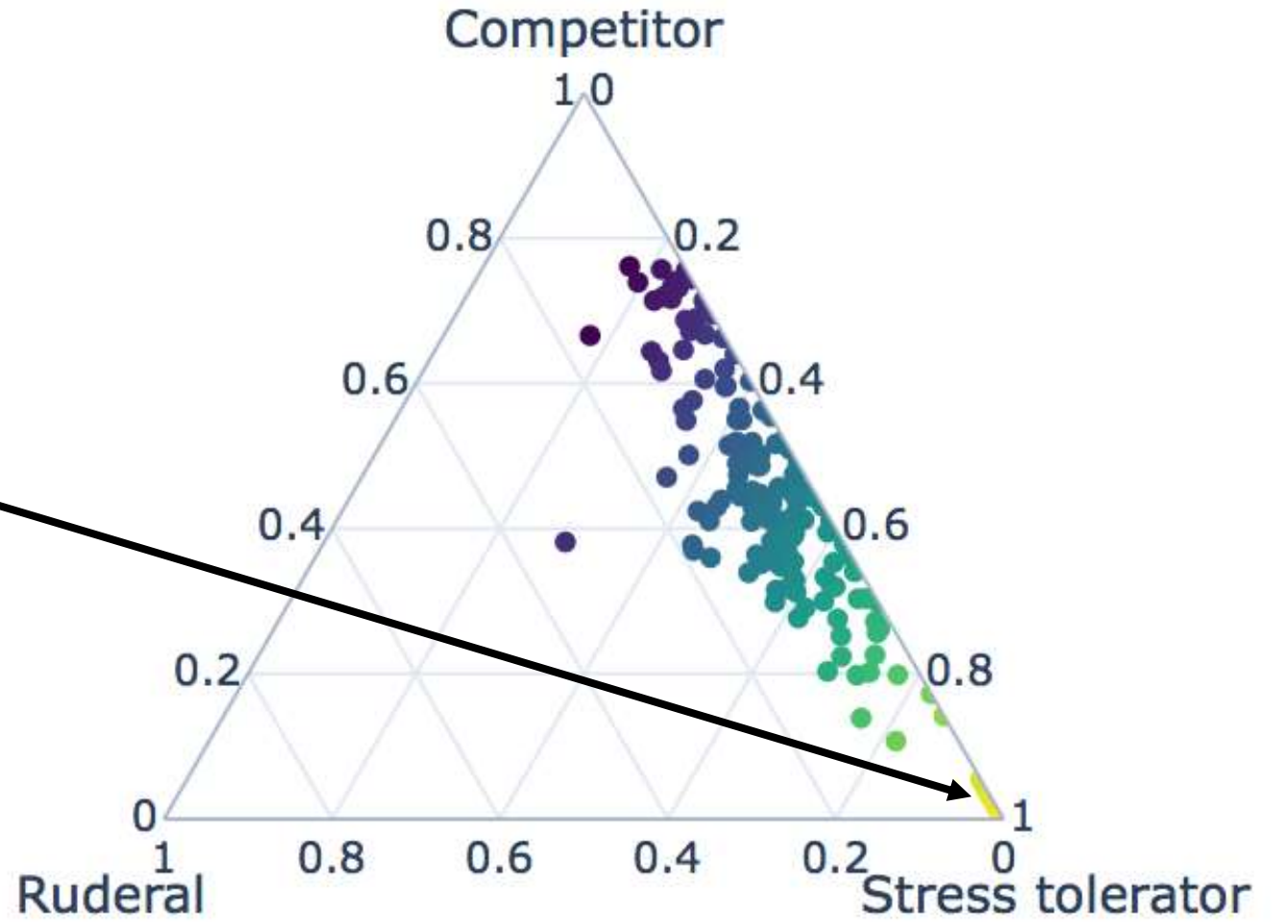


(Sjöman, Hiron and Watkins, 2025)

Pinus leucodermis

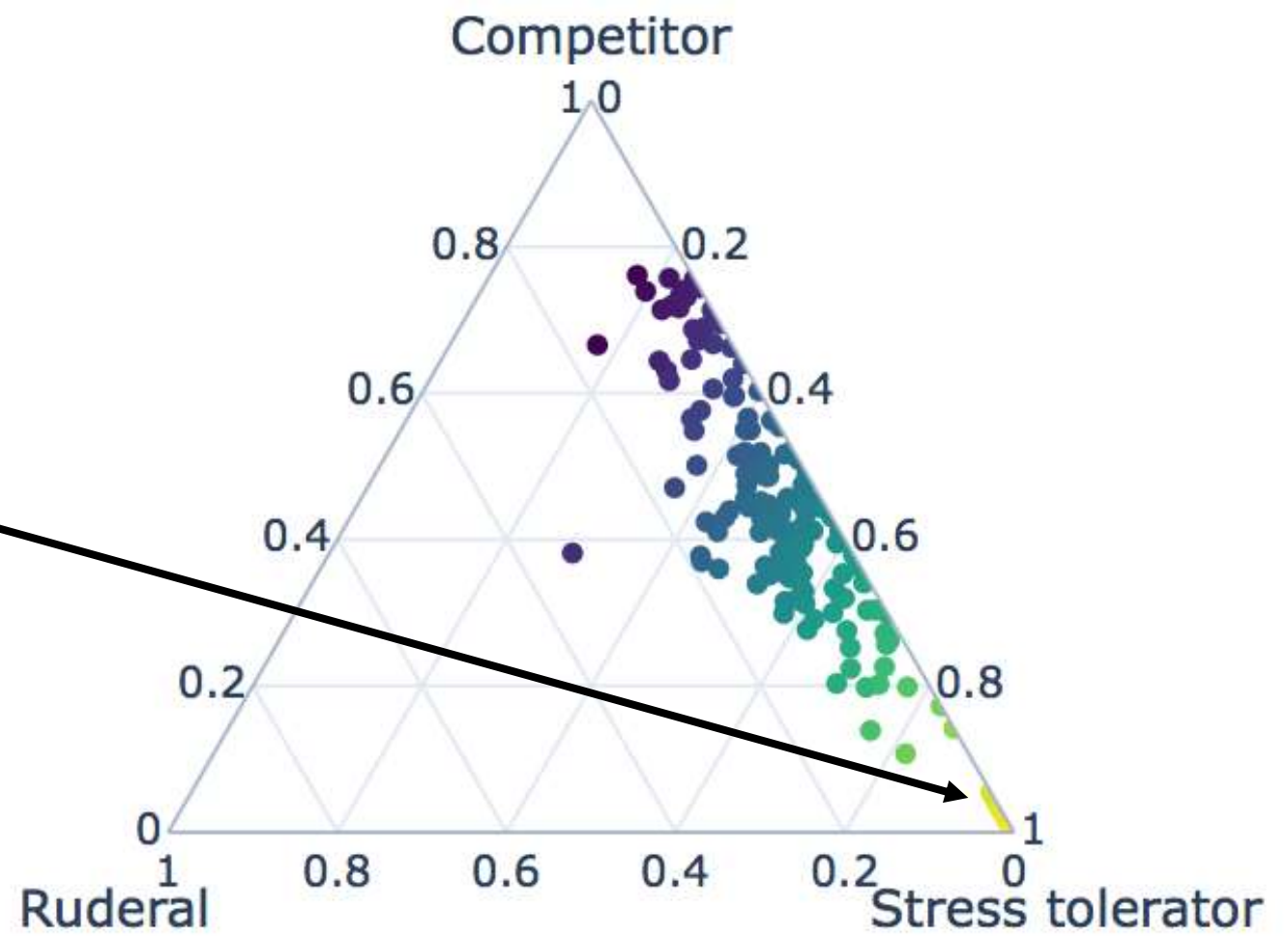


Pinus sylvestris



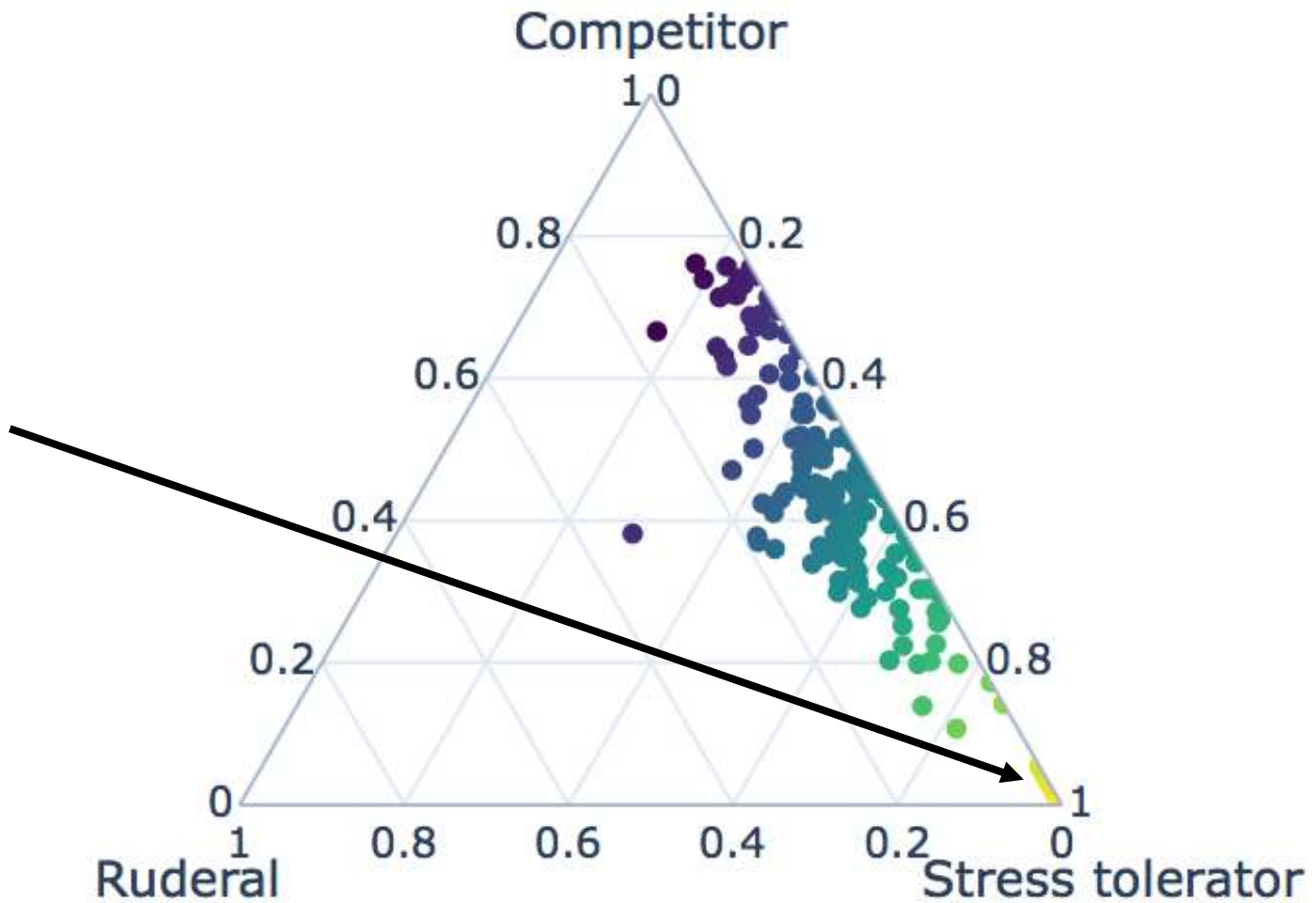
(Sjöman, Hiron and Watkins, 2025)

Tsuga heterophylla



(Sjöman, Hiron and Watkins, 2025)

Abies homolepis

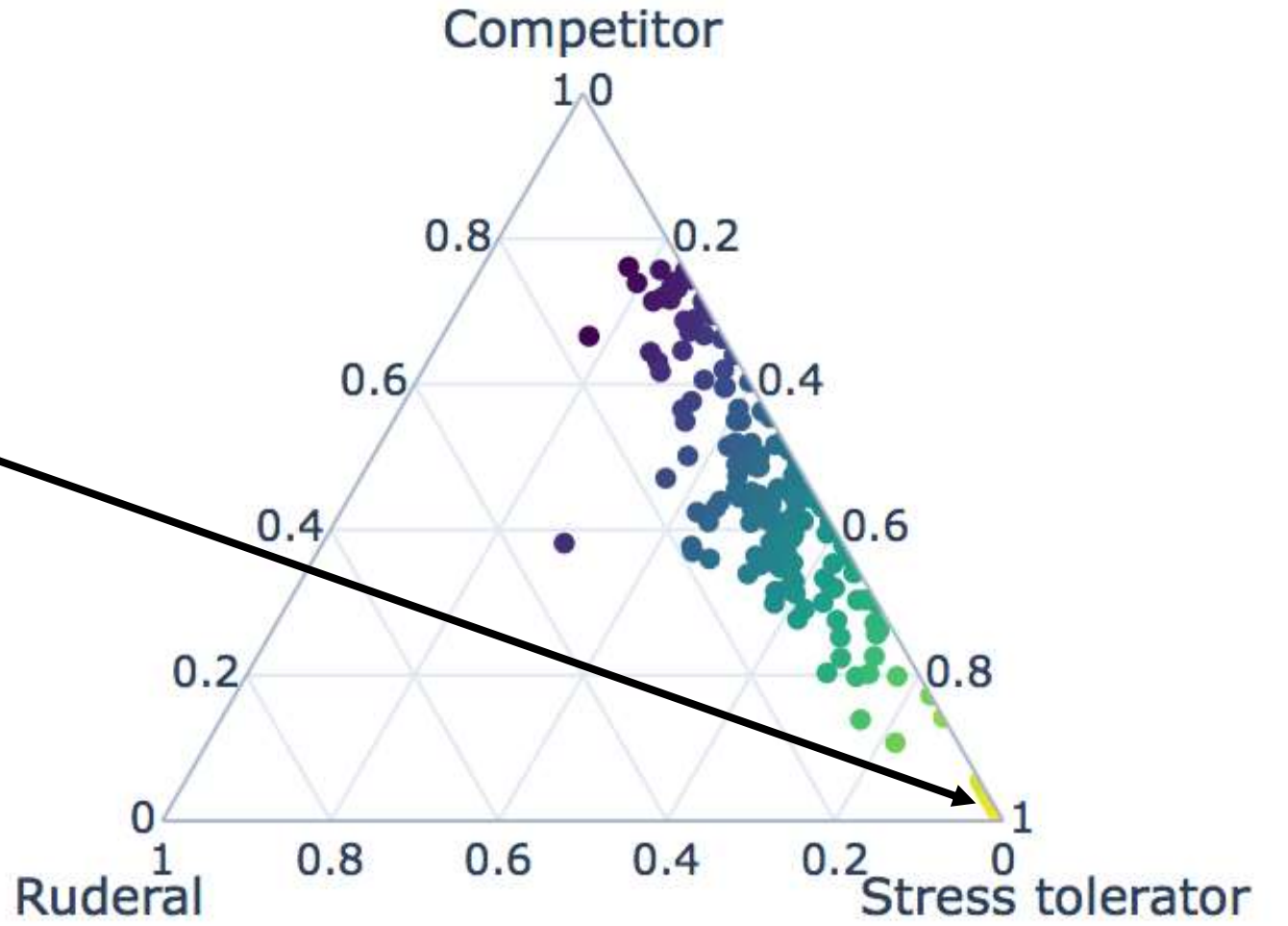


(Sjöman, Hiron and Watkins, 2025)

Abies procera

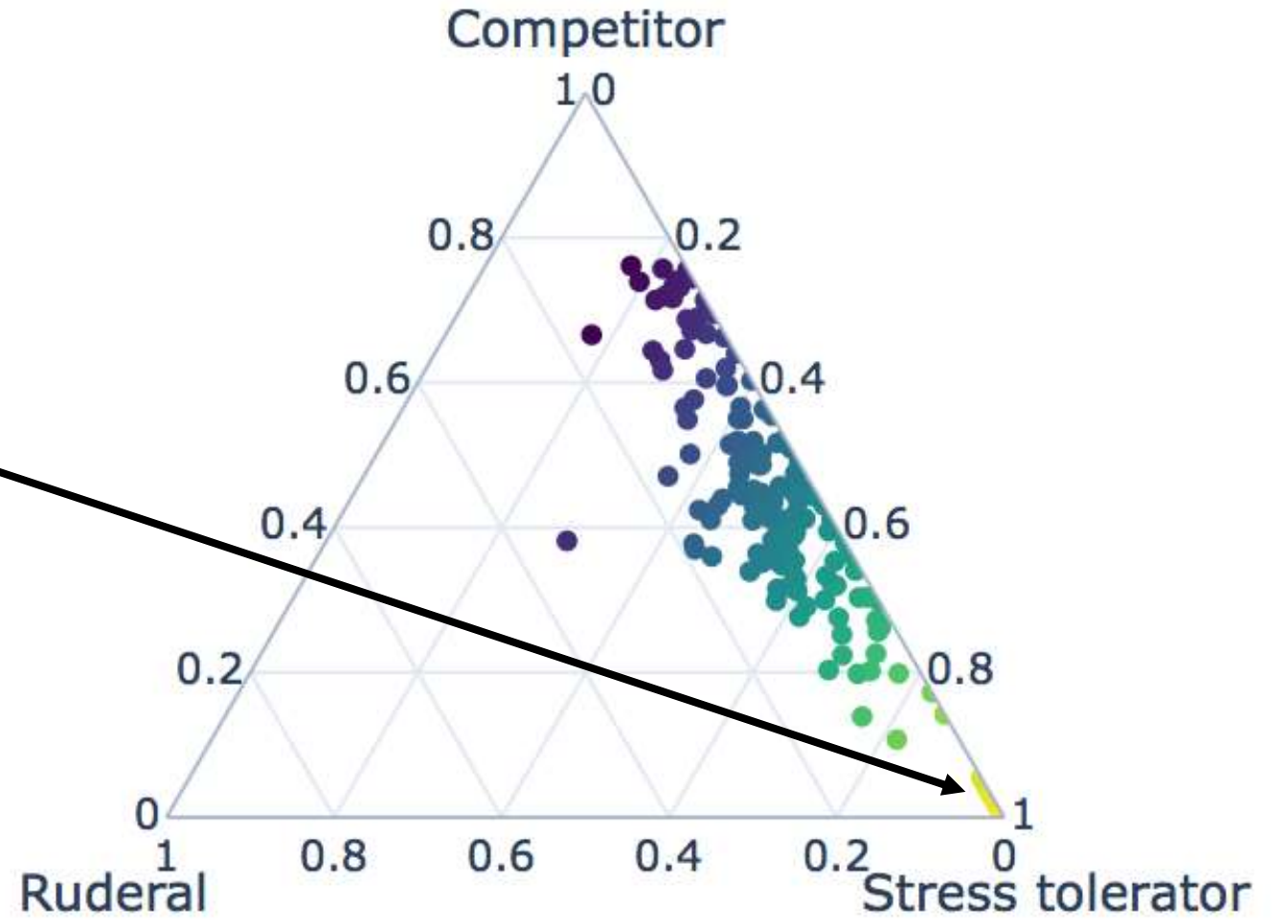


Abies nordmanniana



(Sjöman, Hirons and Watkins, 2025)

Taxus baccata



(Sjöman, Hiron and Watkins, 2025)

Limitations

- Variation in provenance and ecotype may lead different populations to be orientated slightly differently
- Additional species from different arboreta would add value
- ‘Stress’ is not a discrete criteria as stress can have many forms
 - CSR tends to aggregate stresses (*e.g.*, shade, drought, heat) so if information is required on a specific stress, alternative methods may be more effective.





Working in collaboration for better places

The Trees and Design Action Group (TDAG), brings together individuals, professionals, academics and organisations from wide ranging disciplines in both the public and private sectors to improve knowledge and good practice to support the role of urban trees through better collaboration in the planning, design, construction and management and maintenance of our urban places.

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News

Tree Species Selection for Green Infrastructure now available as French and Dutch versions



The success of *Tree Species Selection for Green Infrastructure* within the UK has led to a collaboration between TDAG and [Environnement.brussels](#), to bring the evidence-based guidance to new audiences in Belgium and beyond. We are proud to announce that this guide is now available in French and Dutch from the 'Our Guides' page above. These direct translations of the original English version will expand the value of the original work and support those specifying trees across a larger region in north-west Europe. Bruxelles Environnement has also published

Core funders



Keuze van boomsoorten voor de groeninfrastructuur:



Uitgave NL 1,4/2023

Choisir les essences d'arbres pour l'infrastructure verte:



Version FR 1,4/2023

Tree Species Selection for Green Infrastructure

A Guide for Specifiers



Issue EN 1,4/2023

Written by:
Dr Andrew Hiron and Dr Henrik Sjöman



Primary Project Funder



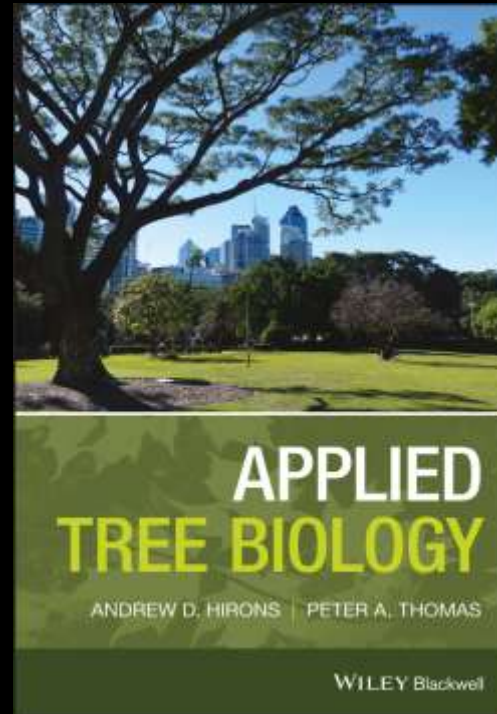
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