# Using CSR theory for selecting woody plants for urban environments

Drs Andrew Hirons, Henrik Sjöman & Harry Watkins

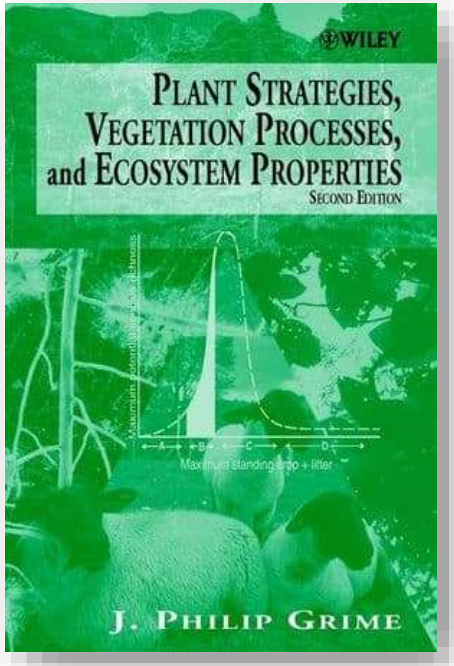
University Centre Myerscough

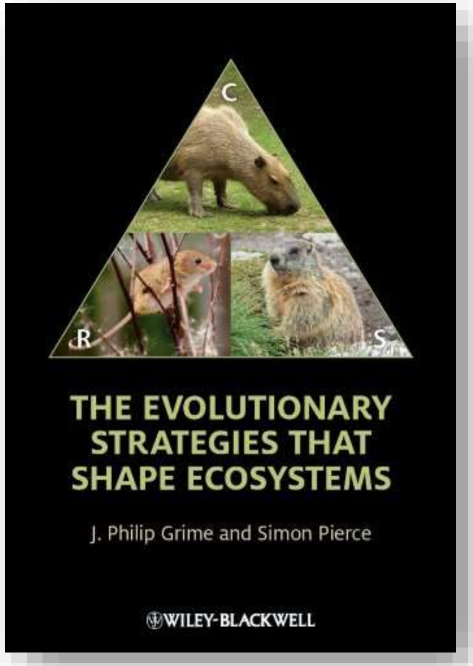
URBAN PLANT LAB

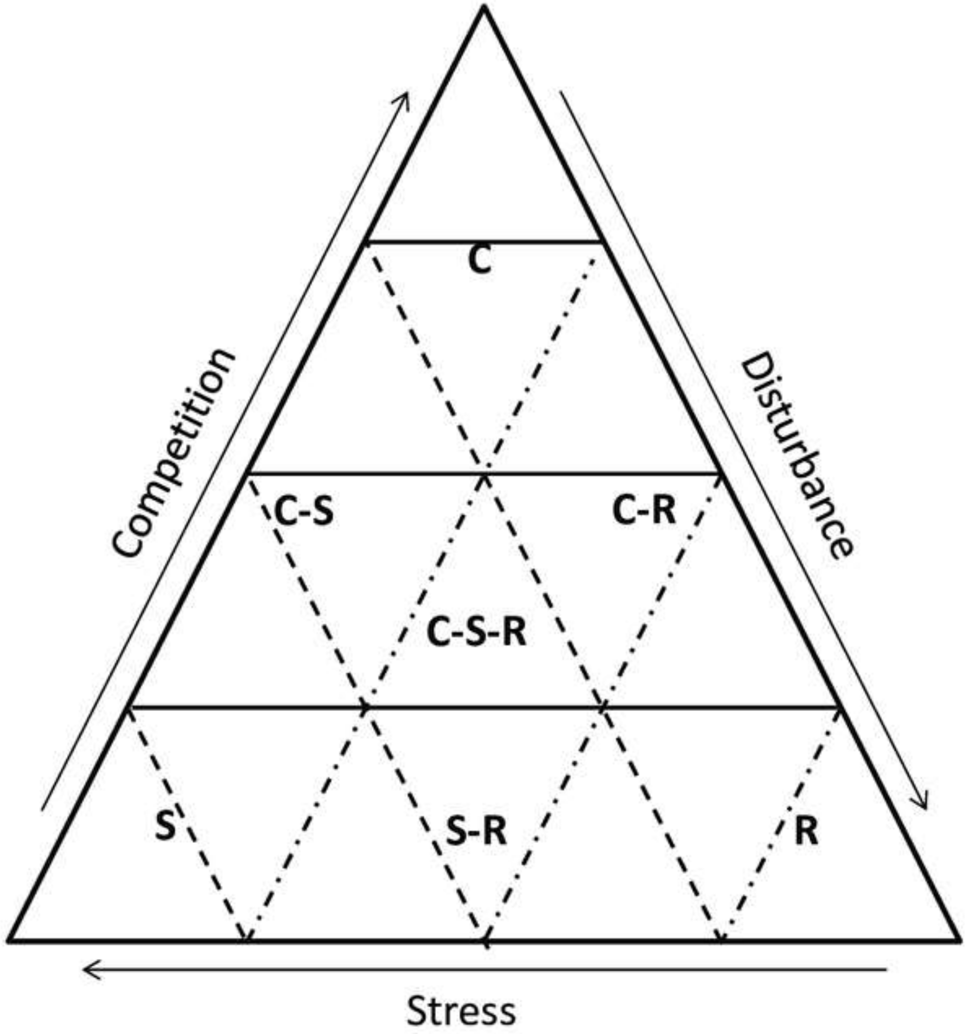
# How do we improve selection decisions?

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

# Roots of ecological theory



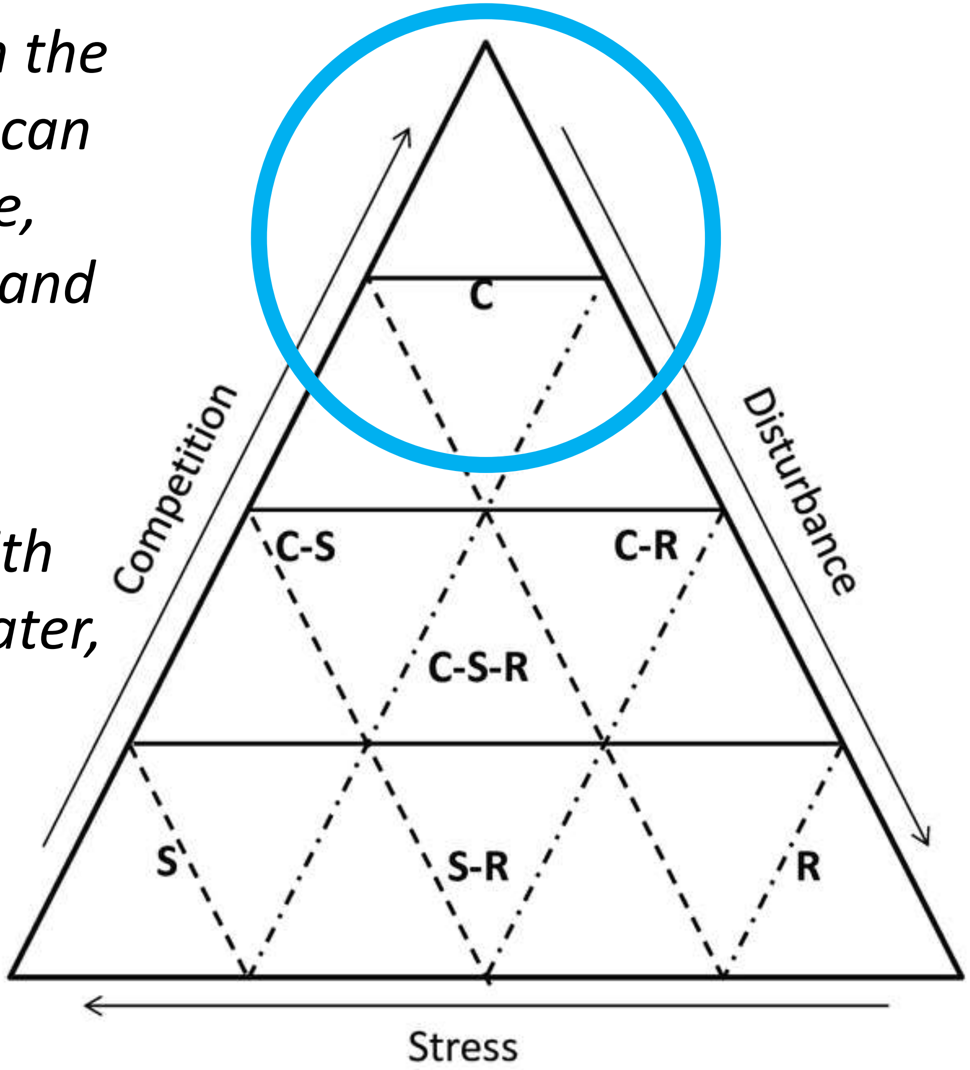



# Competitors | C-Strategists

***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.*

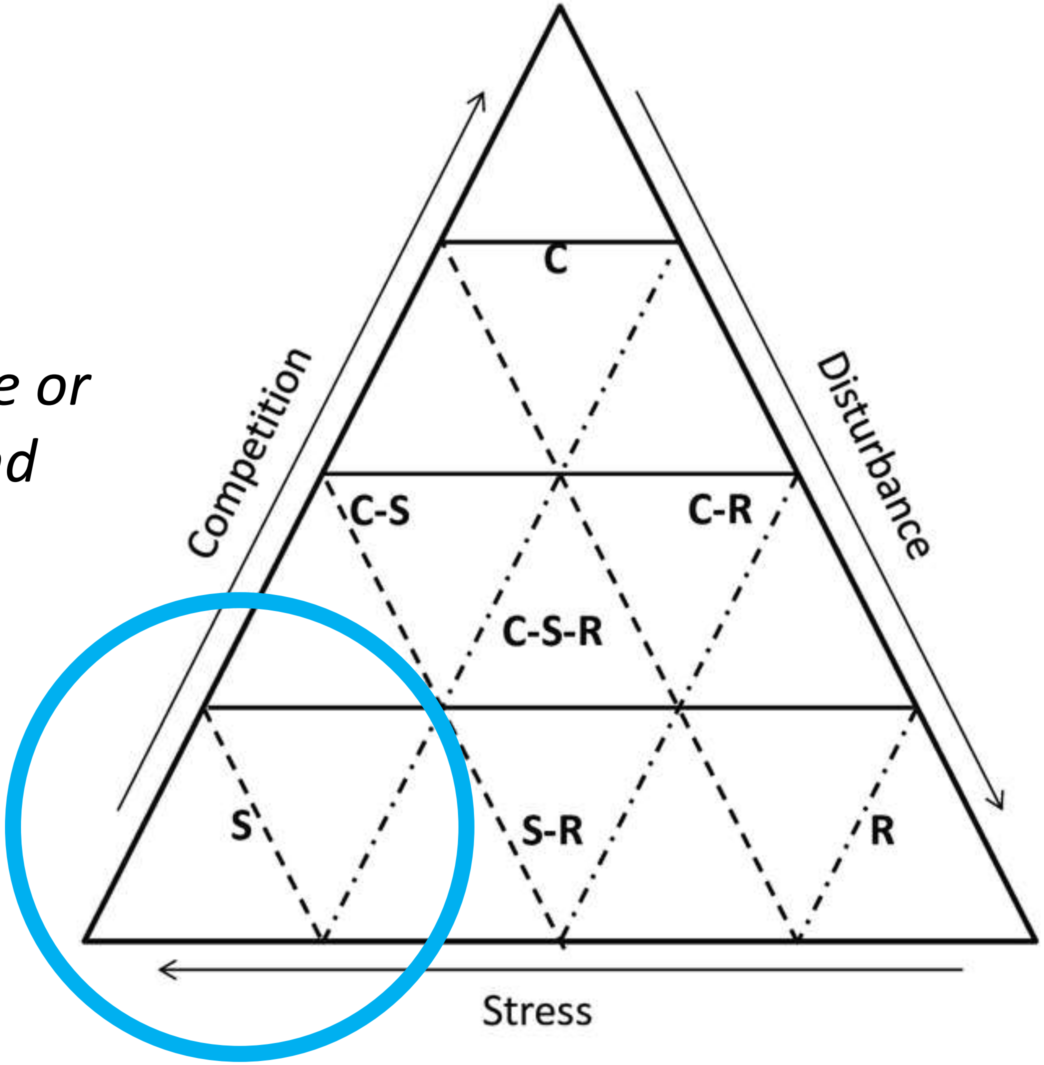
*These trees grow in habitats with high amounts of resources – water, nutrient etc. In dry and poorer habitats these species are less competitive.*



# Pterocarya fraxinifolia

# Stress tolerators | S-Strategists

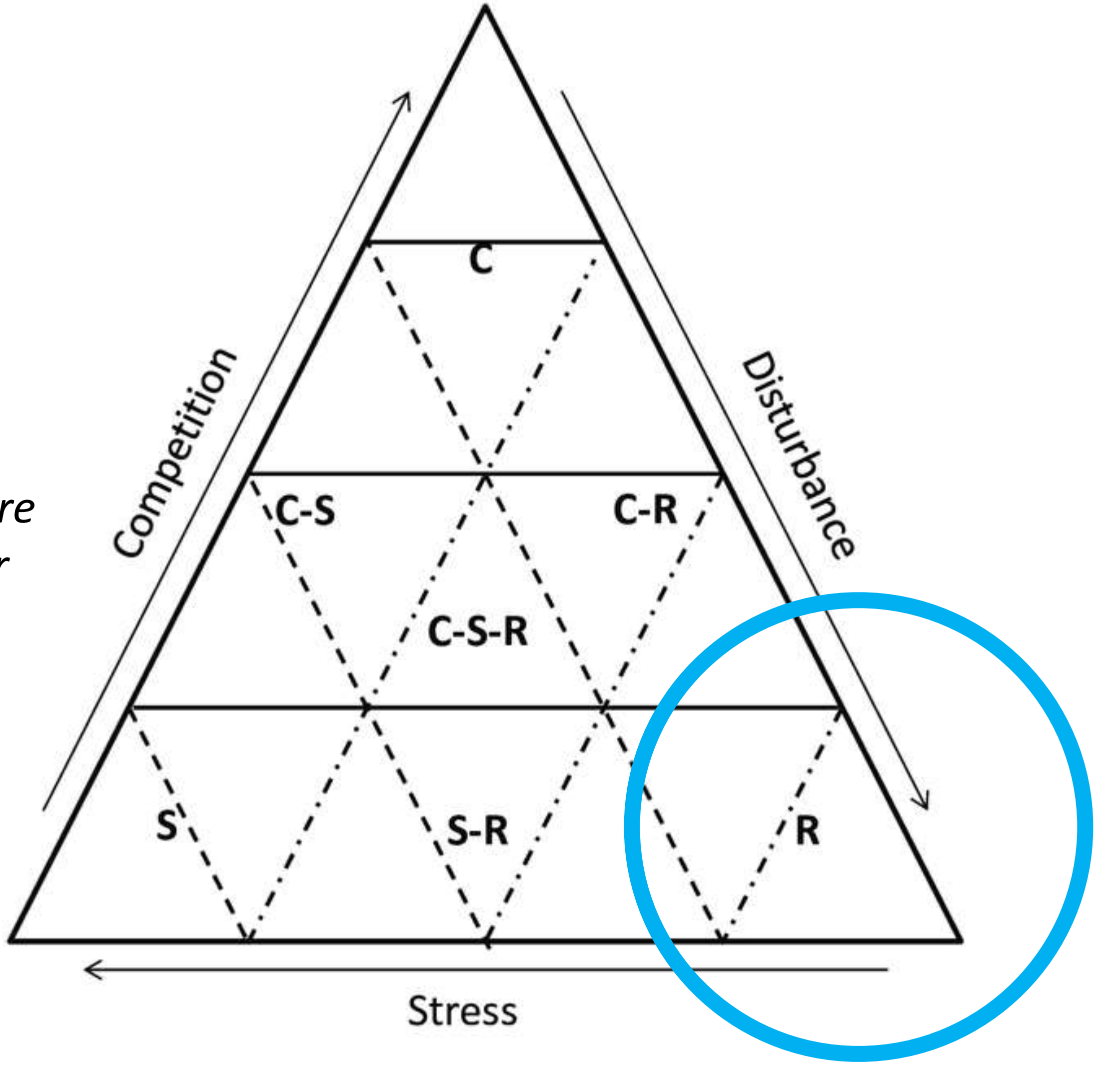
***S-strategists*** *can be tolerant to one or several stress factors e.g. warm and dry habitats, cold temperatures, shade etc.*



*Viburnum lantanoides*

# Ruderals | R-Strategists

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



Functional Ecology

Functional Ecology 2013

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

Simon Pierce*,1, Guido Brusa2, Ilda Vagge1 and Bruno E. L. Cerabolini2

Summary

Introduction

Functional Ecology

Functional Ecology 2017, 31, 444–457

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

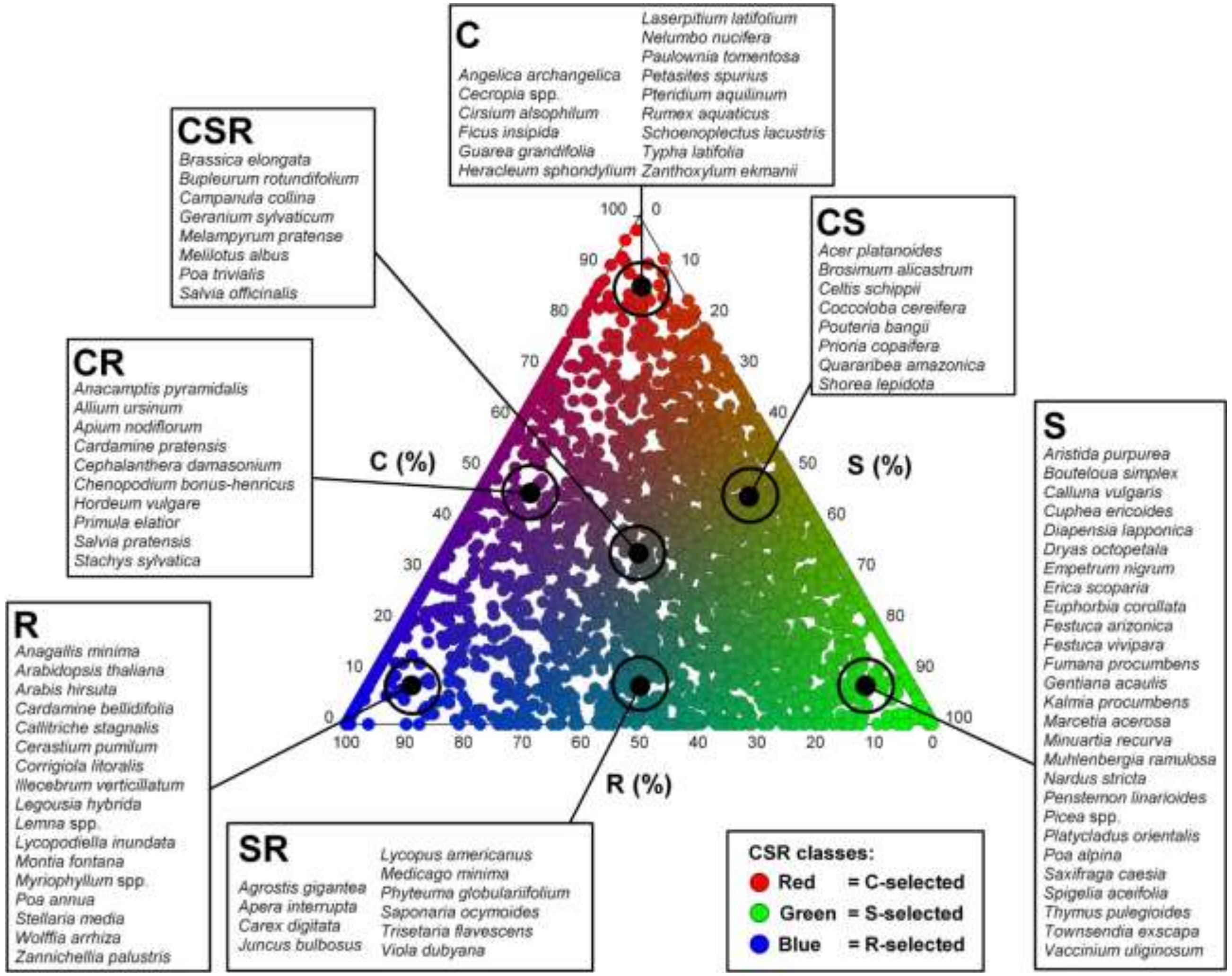
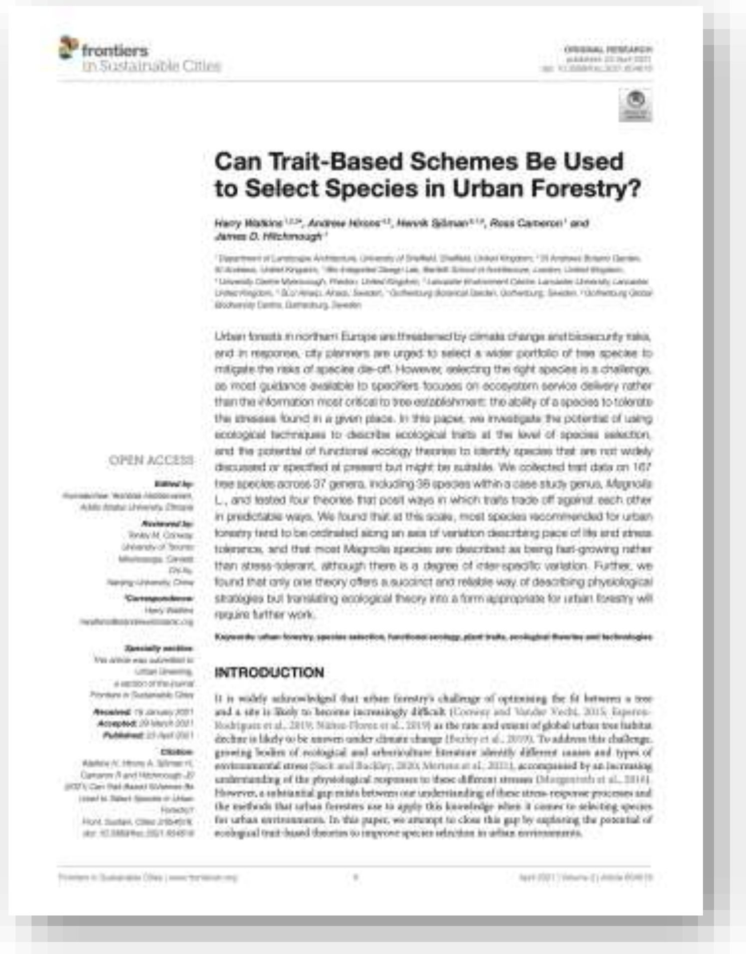



Fig. 3. Relative proportion (%) of C-, S- and R-selection for 3068 tracheophyte species measured from natural habitats across the world, using the globally calibrated CSR analysis tool 'StrateFy'. Species names represent examples of the seven secondary CSR strategy classes (C, CS, CR, CSR, S, SR and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


frontiers in Sustainable Cities

ORIGINAL RESEARCH

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

OPEN ACCESS

INTRODUCTION

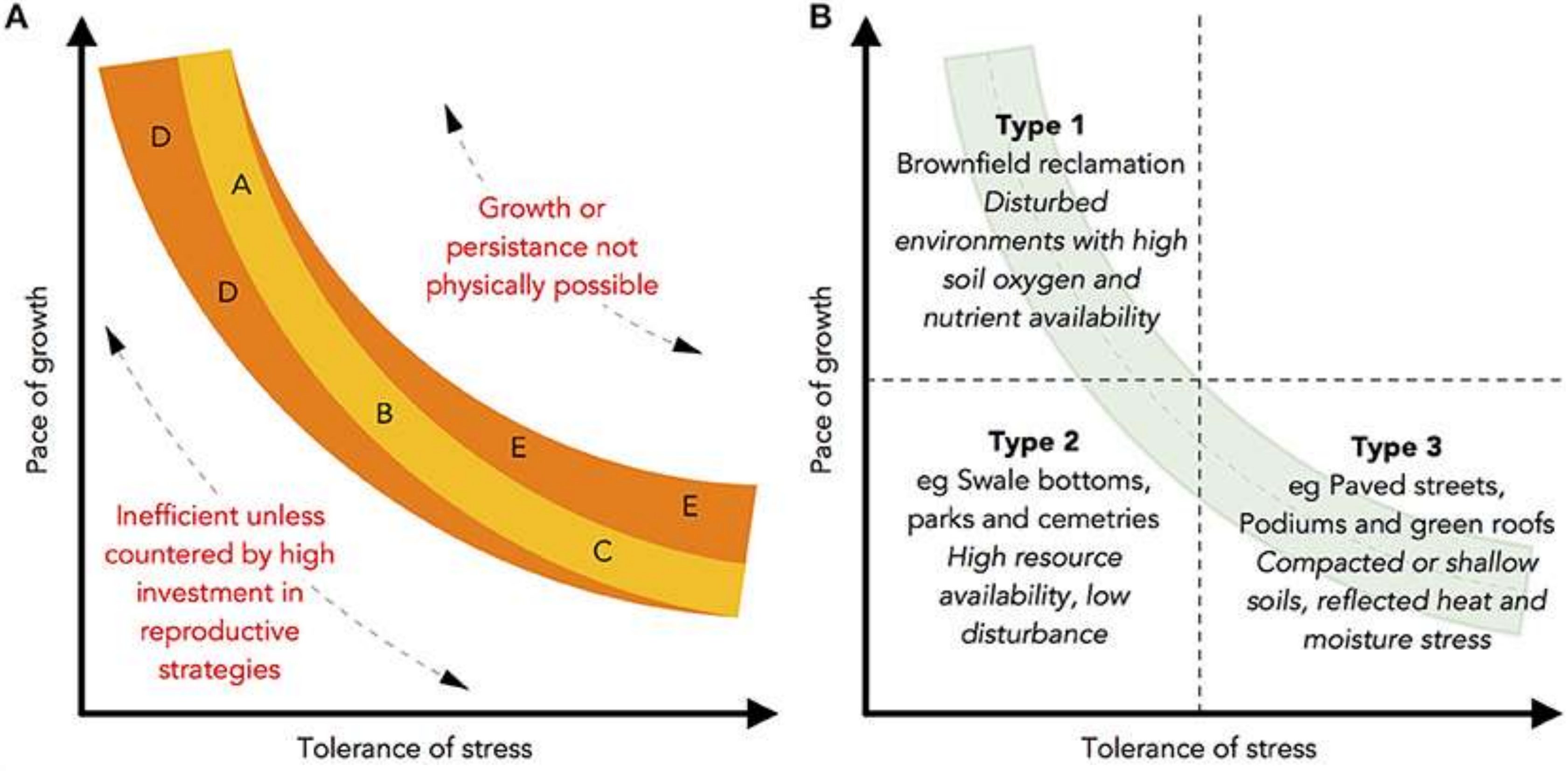



FIGURE 7 | (A,B) Hypothetical trait-based scheme for urban foresters. Building on CSR theory, (A) shows the variety of viable plant strategies in a trade-off between fast growth and high tolerance of stress. Positions A and C equate to different extremes of the trade-offs between competitive-stress tolerant strategies, with position B representing a generalist strategy. A greater investment in reproduction and faster growth is required in disturbed 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.



Arboriculture & Urban Forestry 2025
https://doi.org/ 10.48044/jauf.2025.014

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

By Henrik Sjöman, Andrew Hirons, and Harry Watkins

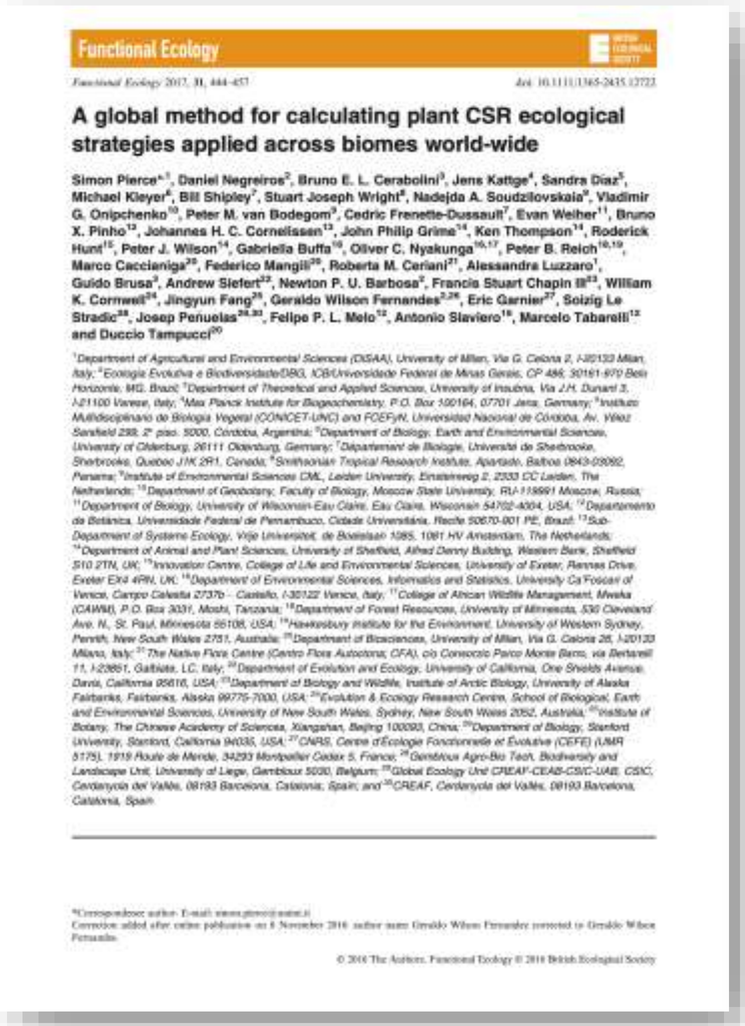
**Abstract.** Background: The development of a framework for optimising plant selection, with the objective of integrating plant resilience for site and function, is crucial for urban forest managers and designers. The principal objective of this study was to evaluate the leaf economics spectrum of trees 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.

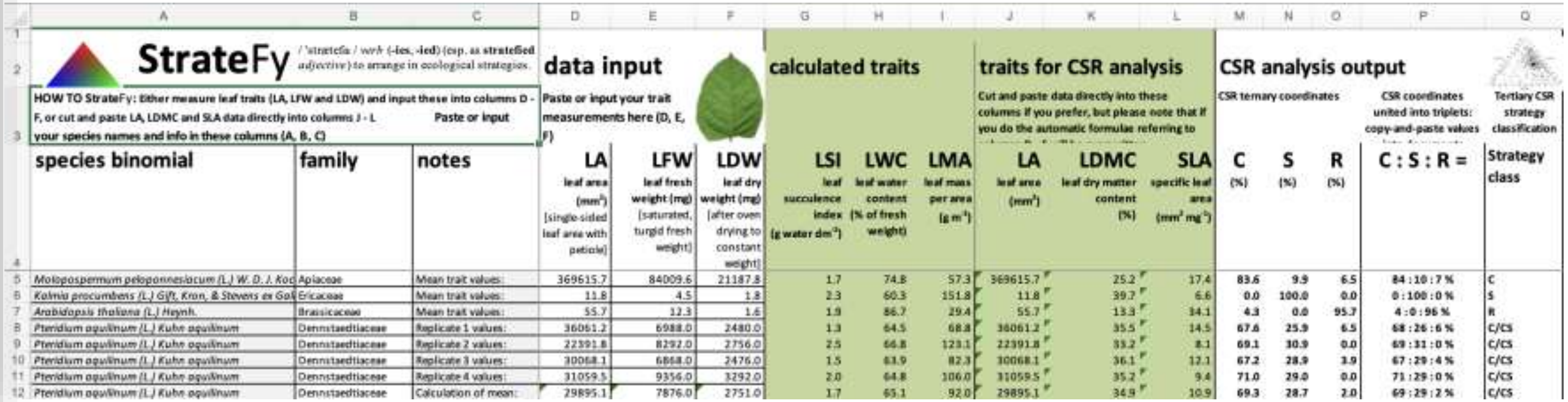
## INTRODUCTION

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. (Kianmehr 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

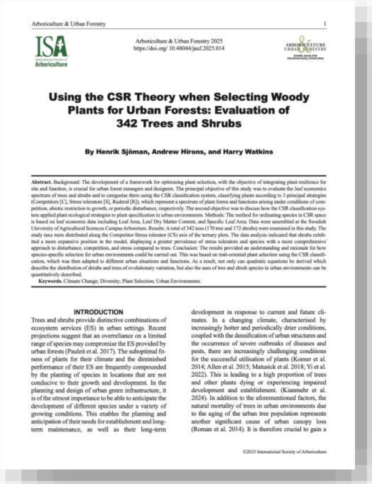
# Method




- Measure leaf area (LA), leaf fresh weight (LFW) and leaf dry weight (LDW)
  - LA
  - LDMC
  - SLA
- C : S : R



# Alnarp Arboretum Study, Sweden





Arboriculture & Urban Forestry 2025
https://doi.org/ 10.48044/jauf.2025.014

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

By Henrik Sjöman, Andrew Hirons, 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.

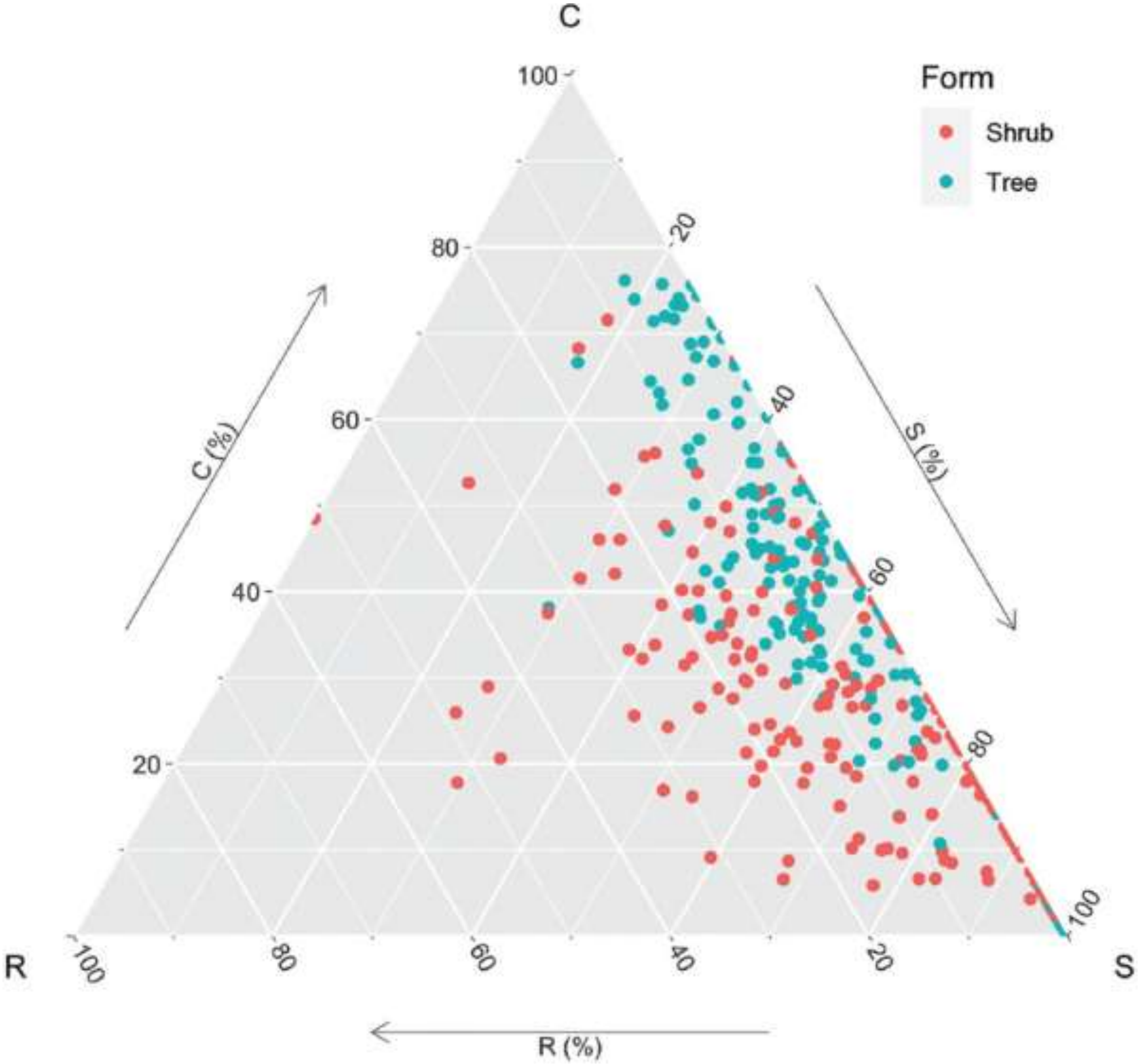
**Keywords.** Climate Change; Diversity; Plant Selection; Urban Environments.

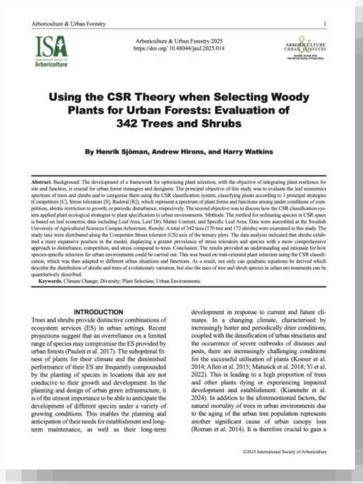
### INTRODUCTION

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. (Kianmehr 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



- Trees and shrubs occupy a similar range, focused on the Competitor-Stress tolerator axis (C-S axis)




Arboriculture & Urban Forestry 2025

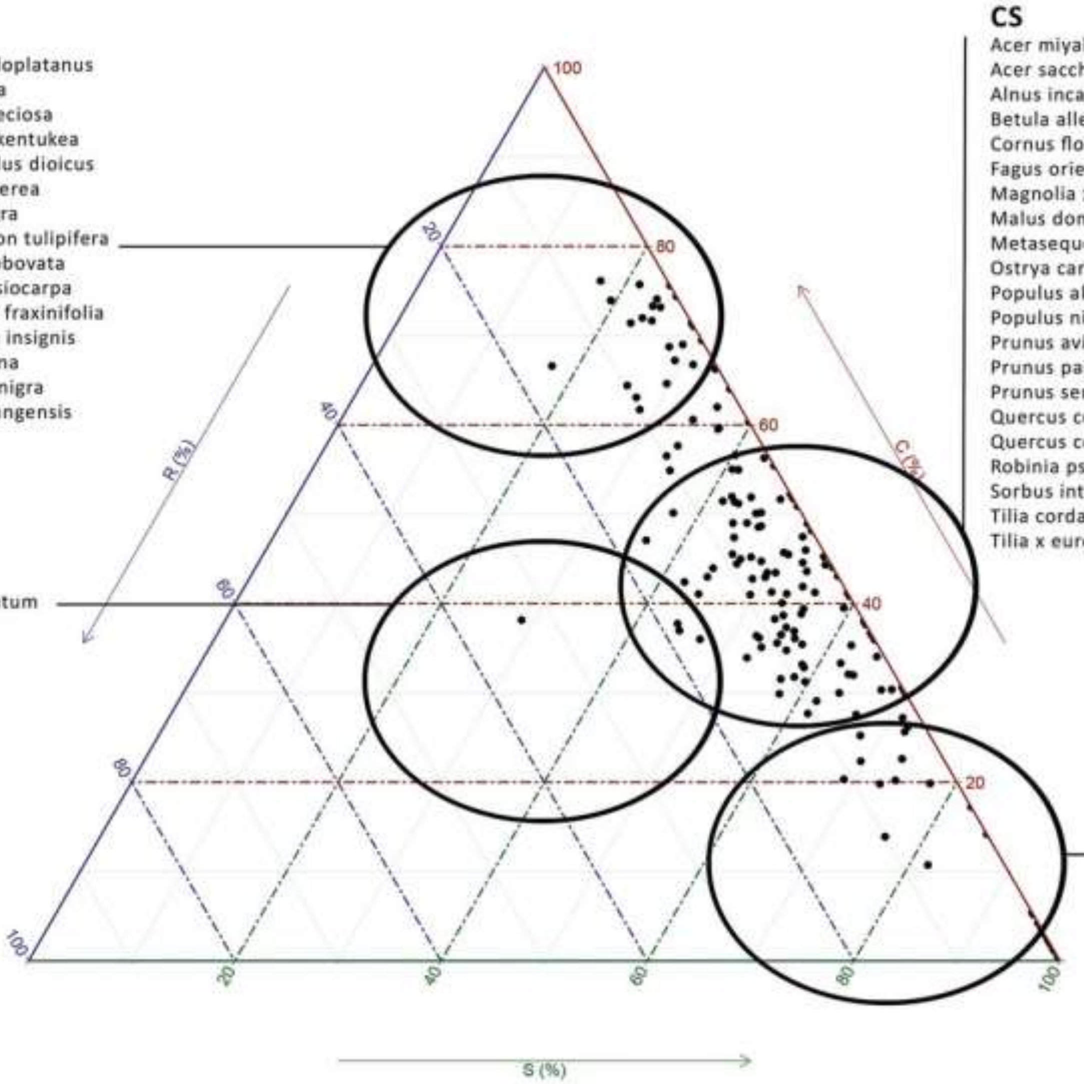
**Using the CSR Theory when Selecting Woody Plants for Urban Forests: Evaluation of 342 Trees and Shrubs**

By Henrik Sjöman, Andrew Hirons, and Harry Watkins

# Trees growing in Alnarp Arboretum, Sweden

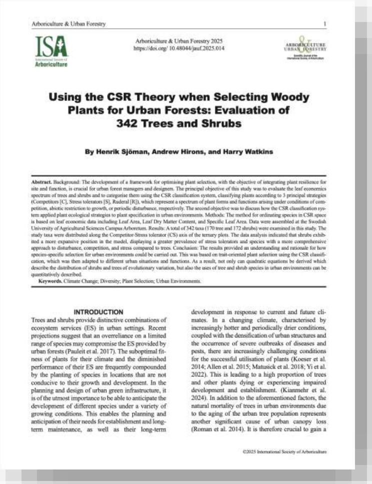
**C**
Acer pseudoplatanus
Carya ovata
Catalpa speciosa
Cladastris kentukea
Gymnocladus dioicus
Juglans cinerea
Juglans nigra
Liriodendron tulipifera
Magnolia obovata
Populus lasiocarpa
Pterocarya fraxinifolia
Pterocarua insignis
Rhus typhina
Sambucus nigra
Sorbus ullungensis

**CSR**
Acer palmatum




**CS**
Acer miyabei
Acer saccharrum
Alnus incana
Betula alleghaniensis
Cornus florida
Fagus orientalis
Magnolia x loebneri
Malus domestica
Metasequoia glyptostroboides
Ostrya carpinifolia
Populus alba
Populus nigra
Prunus avium
Prunus padus
Prunus serotina
Quercus cerris
Quercus coccinea
Robinia pseudoacacia
Sorbus intermedia
Tilia cordata
Tilia x europaea

**S**
Abies homolepis
Abies nordmanniana
Abies pinsapo
Acer monspessulanum
Carpinus orientalis
Carpinus turczaninowii
Elaeagnus angustifolia
Nothofagus antartica
Pinus koraiensis
Pinus leucodermis
Pinus x schwerinii
Taxus cuspidata
Tsuga caroliniana
Tsuga heterophylla
Tsuga mertensiana
Zelkova serrata


Arboriculture & Urban Forestry 1

Arboriculture & Urban Forestry 2025
https://doi.org/ 10.48044/jauf.2025.014

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

**By Henrik Sjöman, Andrew Hirons, 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**

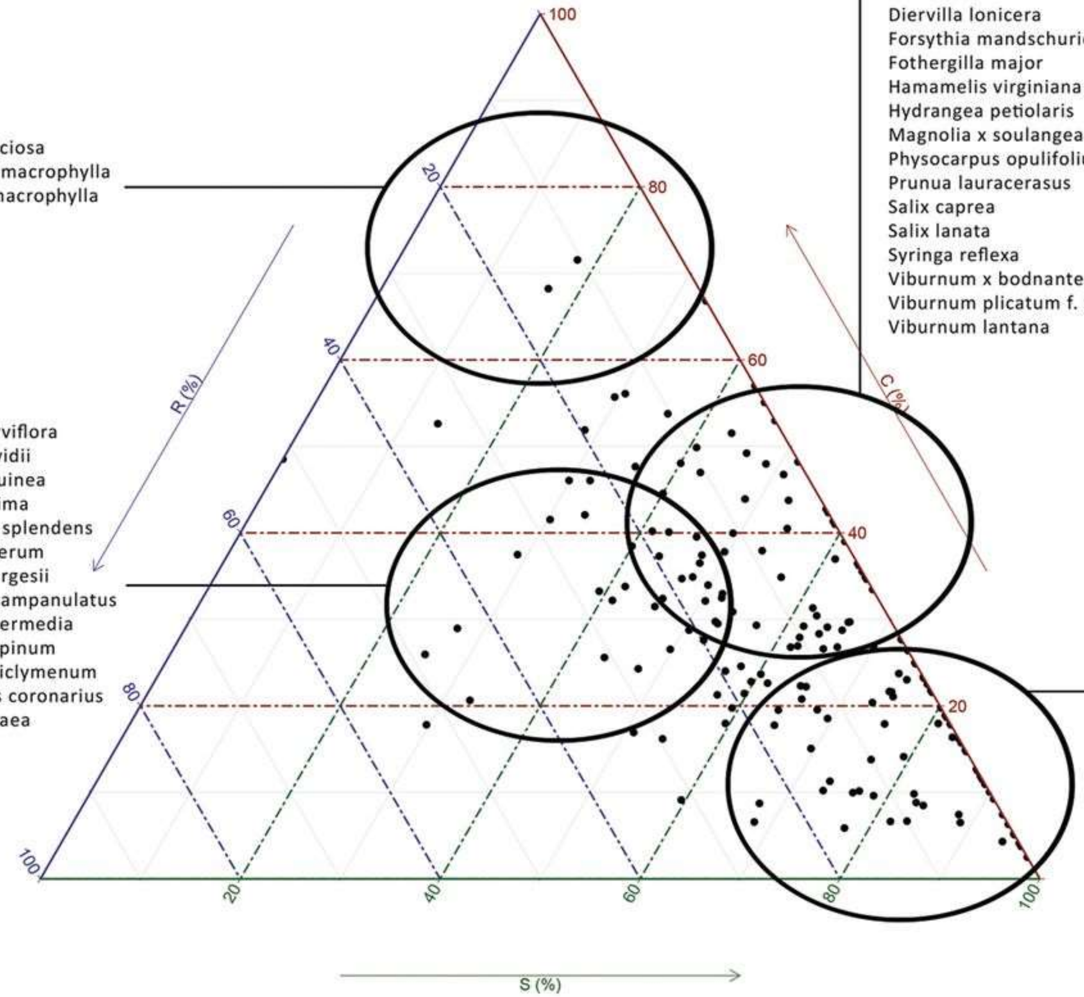
Trees and shrubs provide distinctive combinations of ecosystem services (ES) in urban settings. Recent projections suggest that an overreliance on a limited range of species may compromise the ES provided by urban forests (Pauleit et al. 2017). The suboptimal fitness of plants for their climate and the 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. (Kianmehr 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

©2025 International Society of Arboriculture

# Shrubs growing in Alnarp Arboretum, Sweden

**C**
Actinidia delciosa
Aristolochia macrophylla
Hydrangea macrophylla

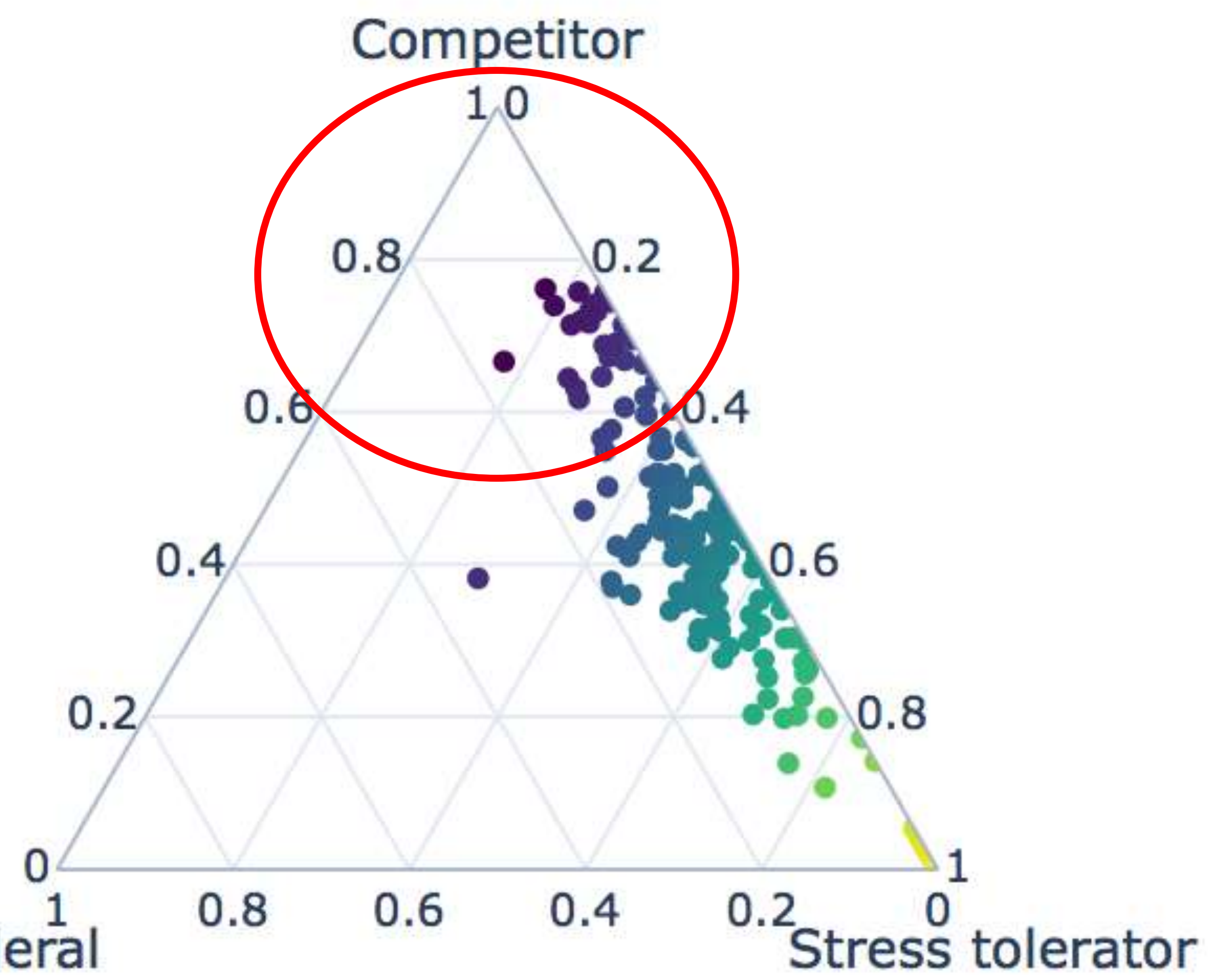
**CSR**
Aesculus parviflora
Buddleja davidii
Cornus sanguinea
Corylus maxima
Cotoneaster splendens
Daphne mezerum
Decaisnea fargesii
Enkianthus campanulatus
Forsythia intermedia
Laburnum alpinum
Lonicera periclymenum
Philadelphus coronarius
Syringa josikaea




**CS**
Acer pensylvanicum
Aronia melanocarpa
Cotinus coggygria
Deutzia scabra
Diervilla lonicera
Forsythia mandschurica
Fothergilla major
Hamamelis virginiana
Hydrangea petiolaris
Magnolia x soulangeana
Physocarpus opulifolius
Prunua lauracerasus
Salix caprea
Salix lanata
Syringa reflexa
Viburnum x bodnantense
Viburnum plicatum f. tomentosum
Viburnum lantana

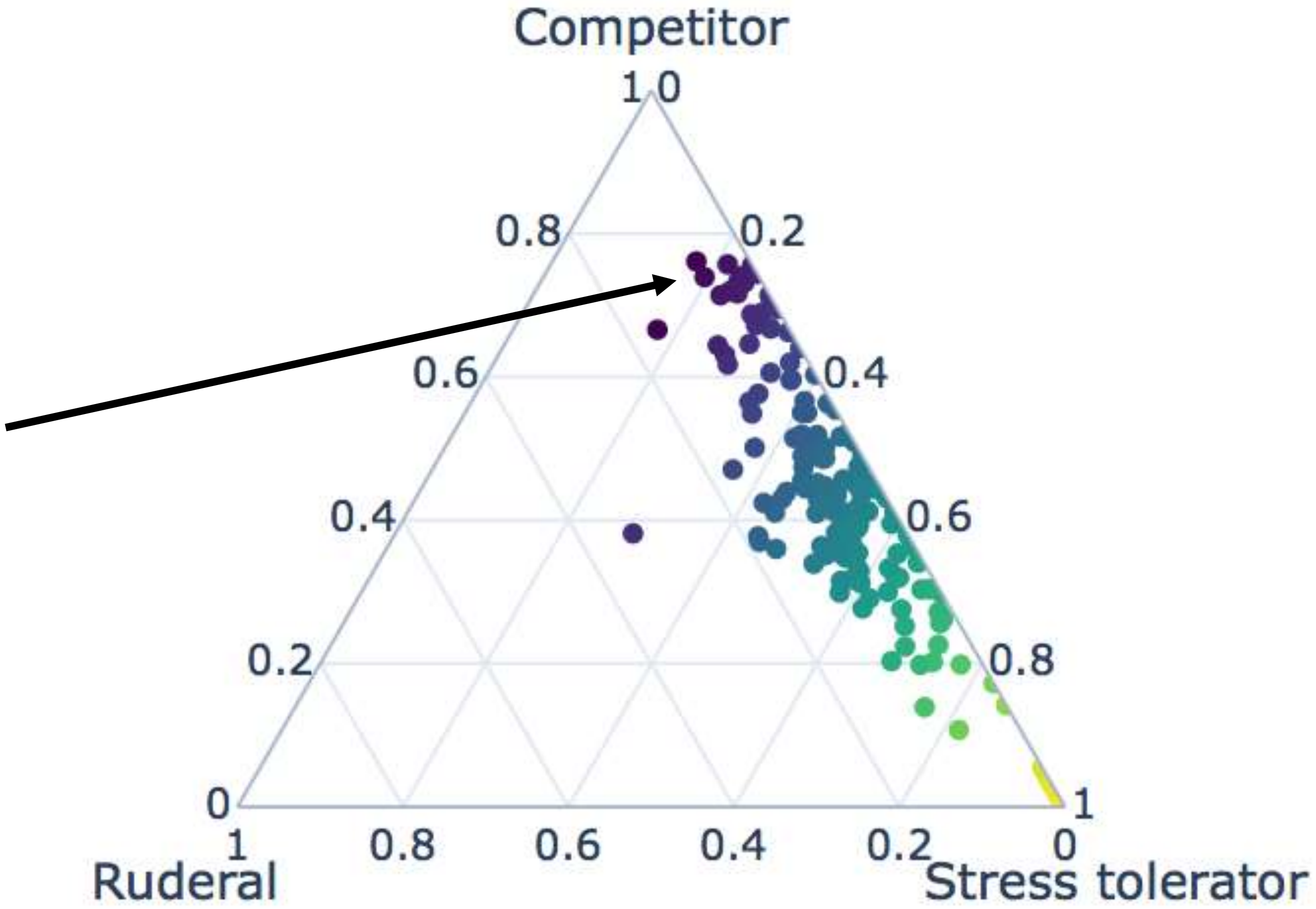
**S**
Berberis x fricartii
Berberis thunbergii
Buxus sempervirens
Cotoneaster apiculatus
Cotoneaster dammeri
Cotoneaster divaricatus
Crataegus laevigata
Crataegus monogyna
Hippophae rhamnoides
Ilex crenata
Ligustrum vulgare
Lonicera nitida
Hypericum kalmianum
Pieris japonica
Potentilla fruticosa
Prunus spinosa
Pyracantha coccinea
Rhododendron catawbiense
Rhus aromatica
Rosa dumalis
Rosa majalis
Rosa rugosa
Salix purpurea
Spiraea x cinerea
Spiraea nipponica
Spiraea trilobata
Symphoricarpus orbiculatus
Taxus baccata
Vinca minor

# CSR ordination of species growing in Alnarp arboretum



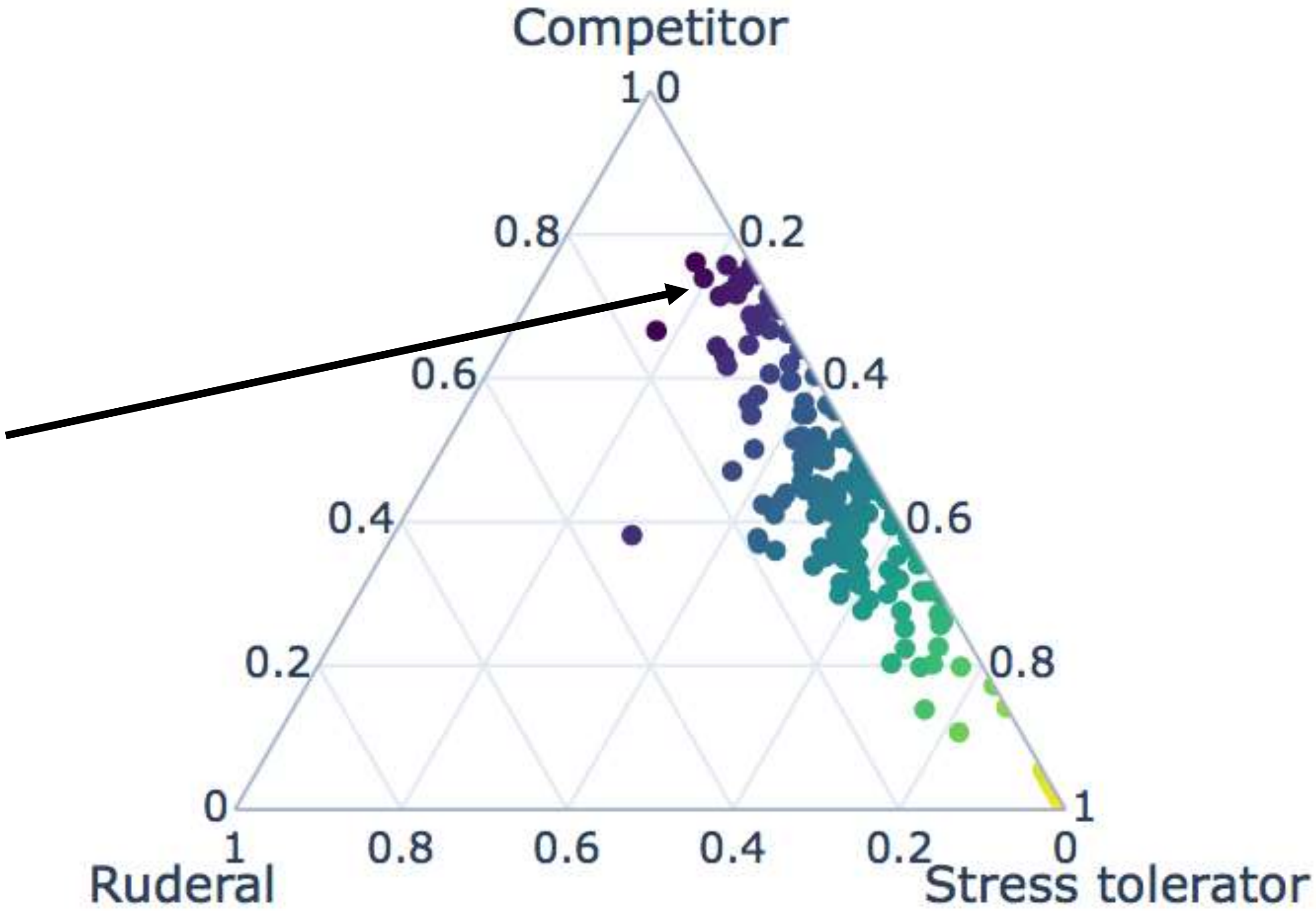

(Sjöman, Hirons and Watkins, 2025)



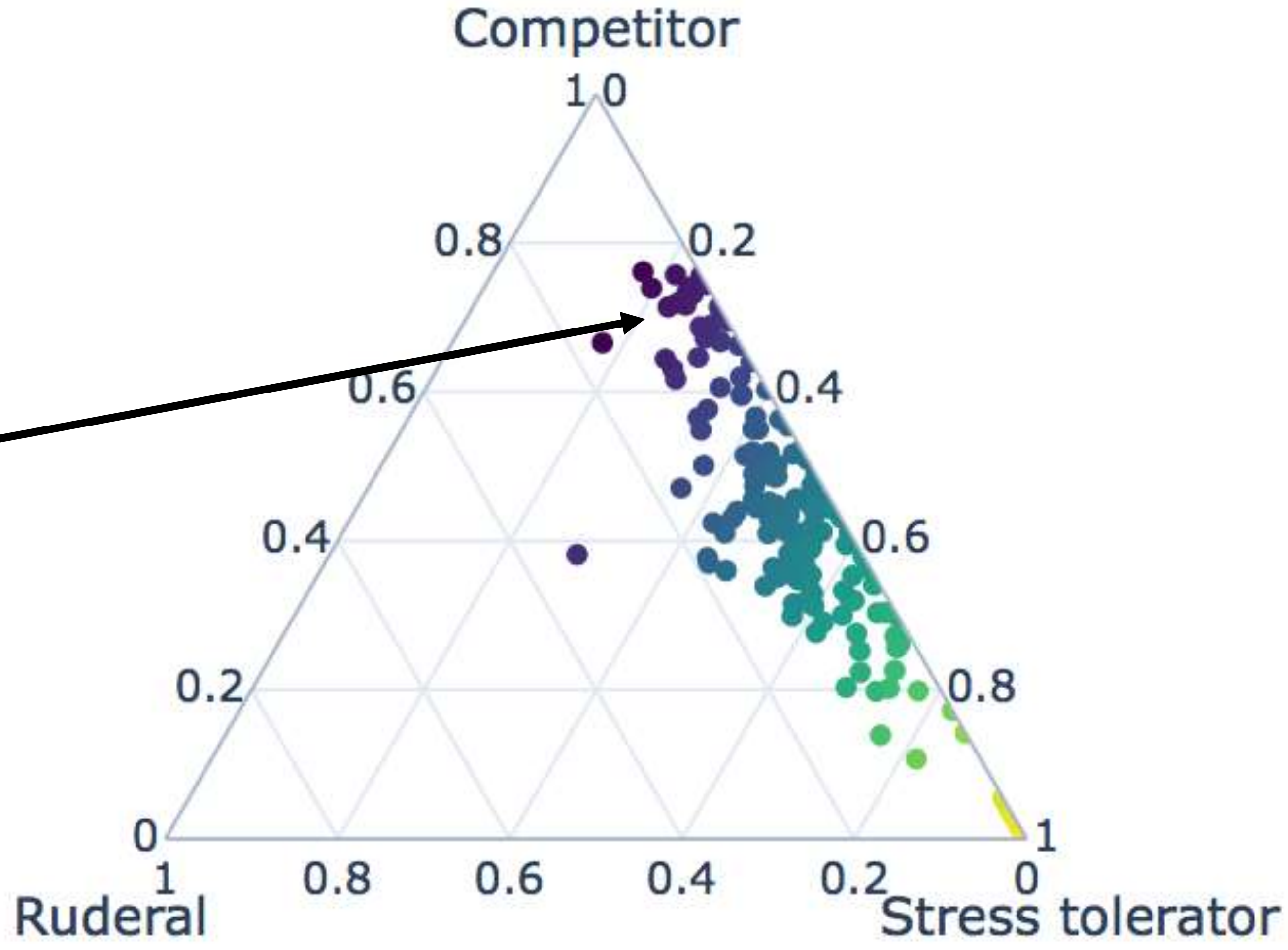



(Sjöman, Hirons and Watkins, 2025)



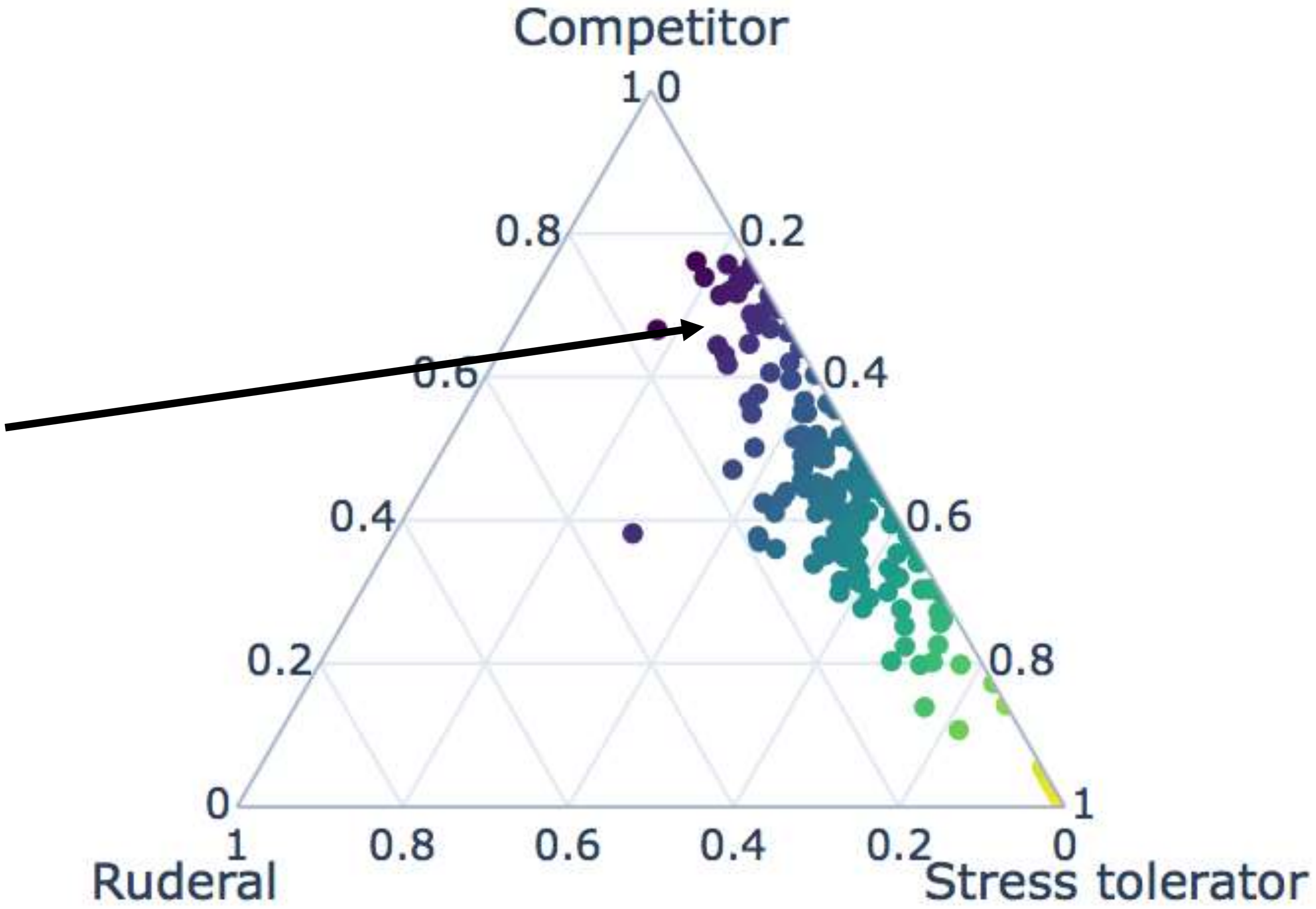



(Sjöman, Hirons and Watkins, 2025)

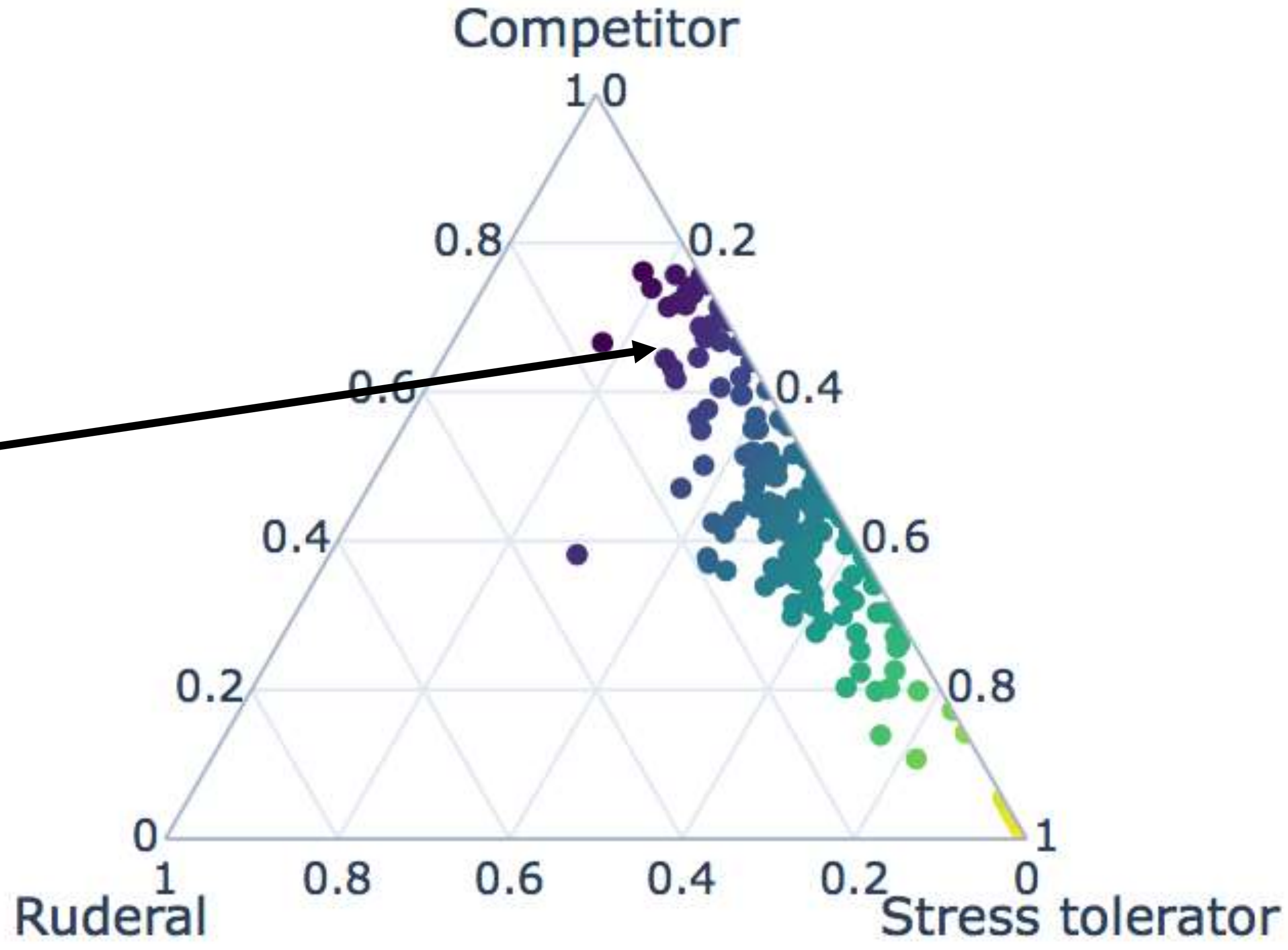




(Sjöman, Hirons and Watkins, 2025)



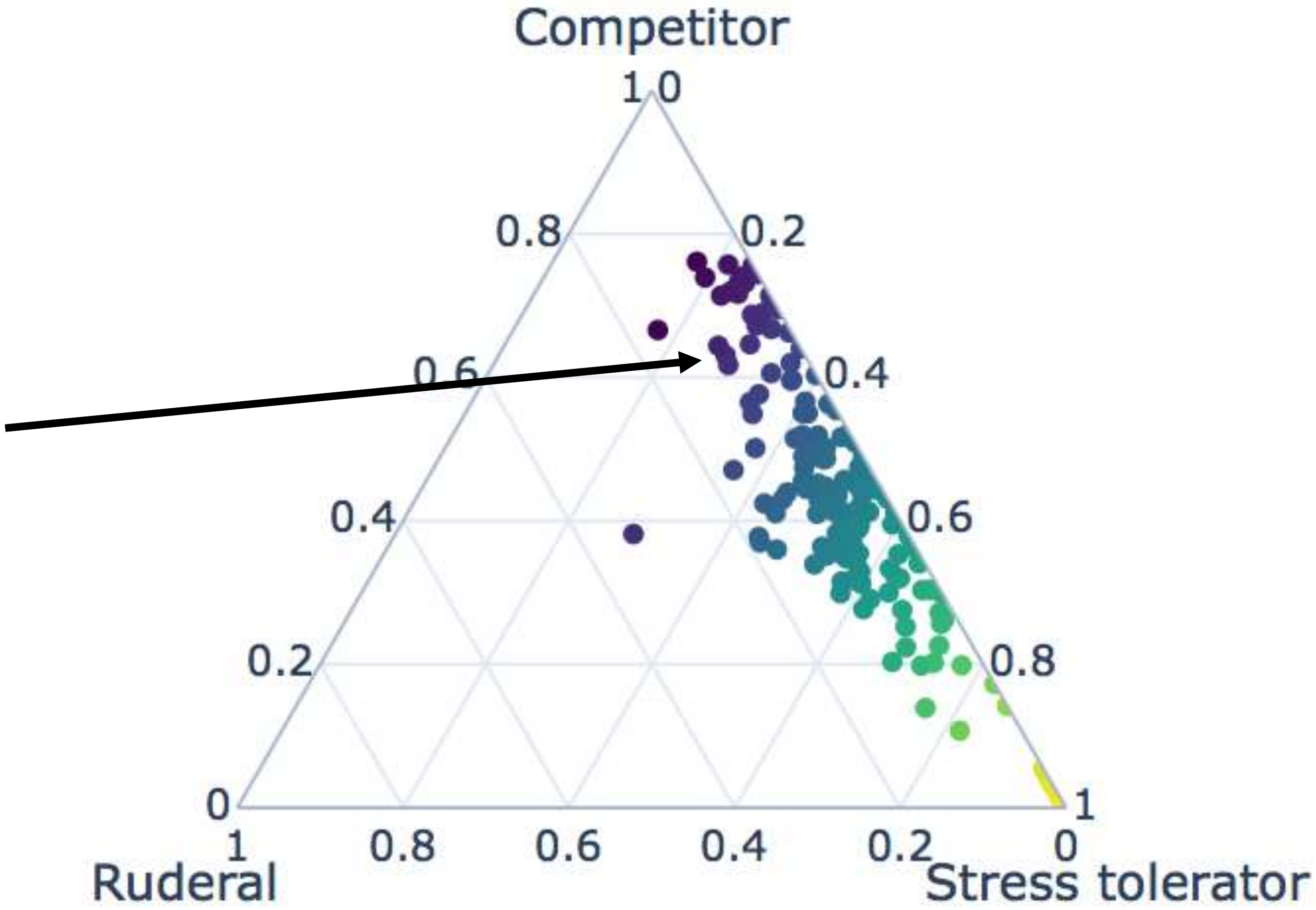



(Sjöman, Hirons and Watkins, 2025)

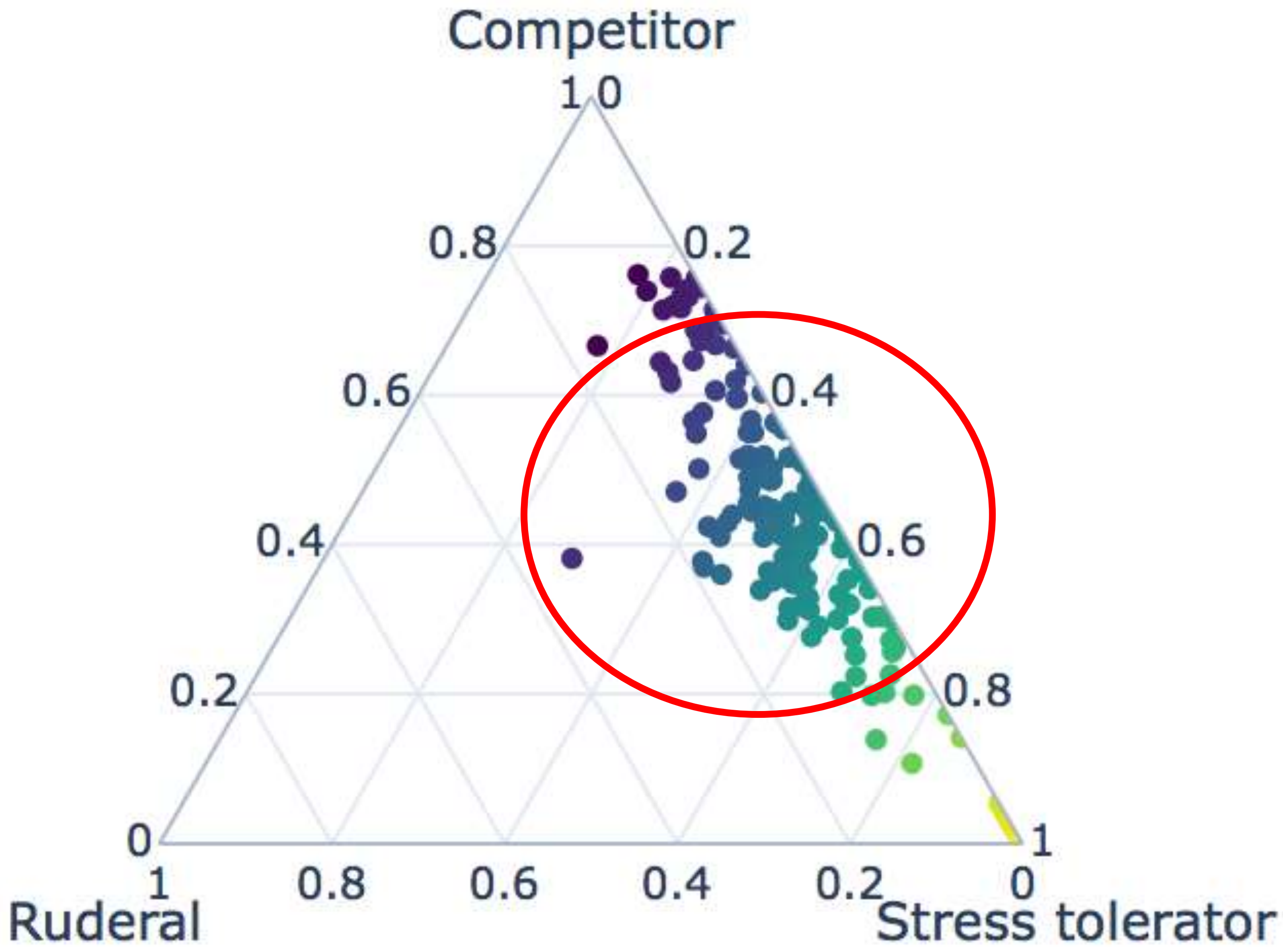

(Sjöman, Hirons and Watkins, 2025)



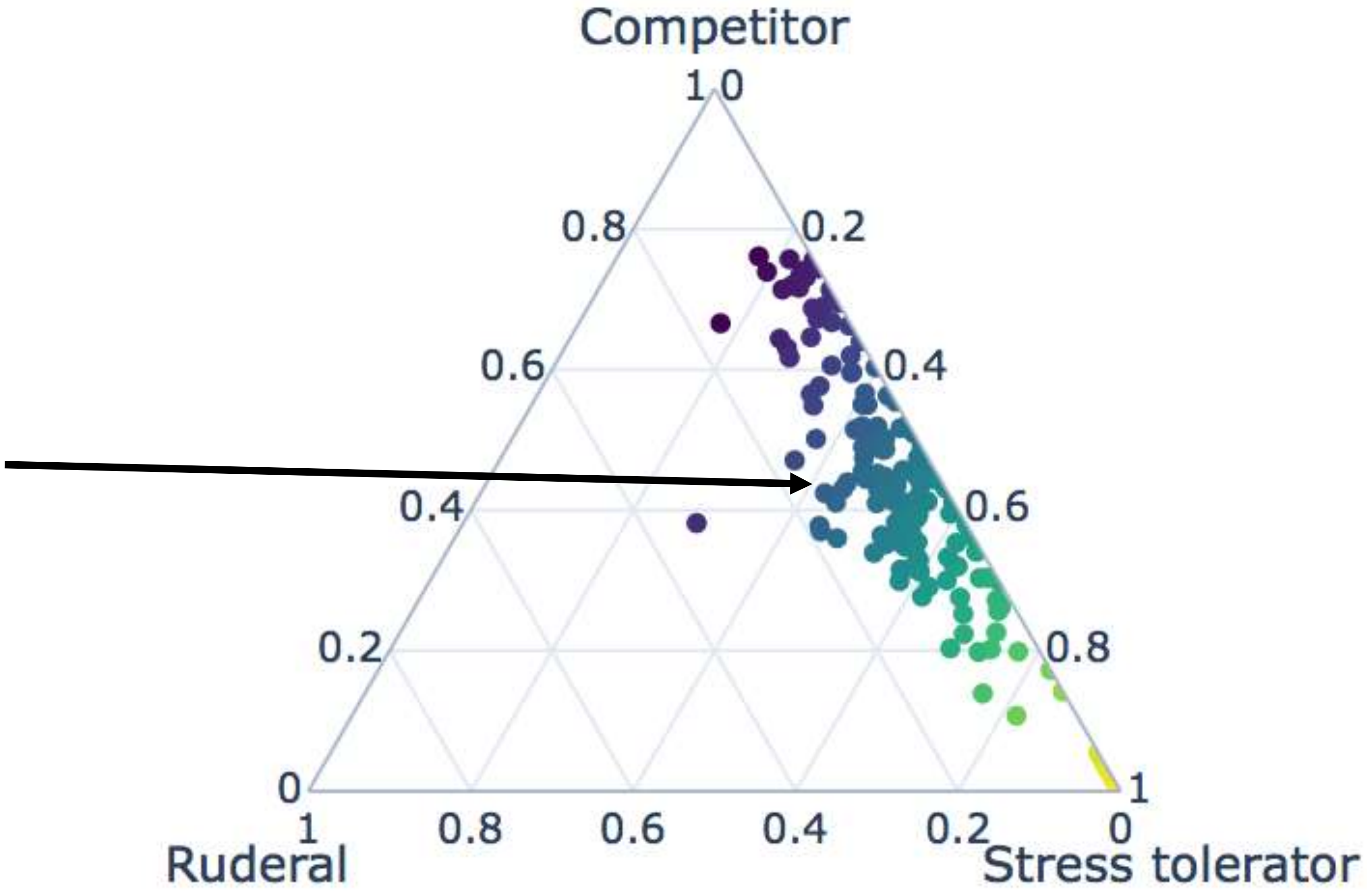



(Sjöman, Hirons and Watkins, 2025)

# CSR ordination of species growing in Alnarp arboretum

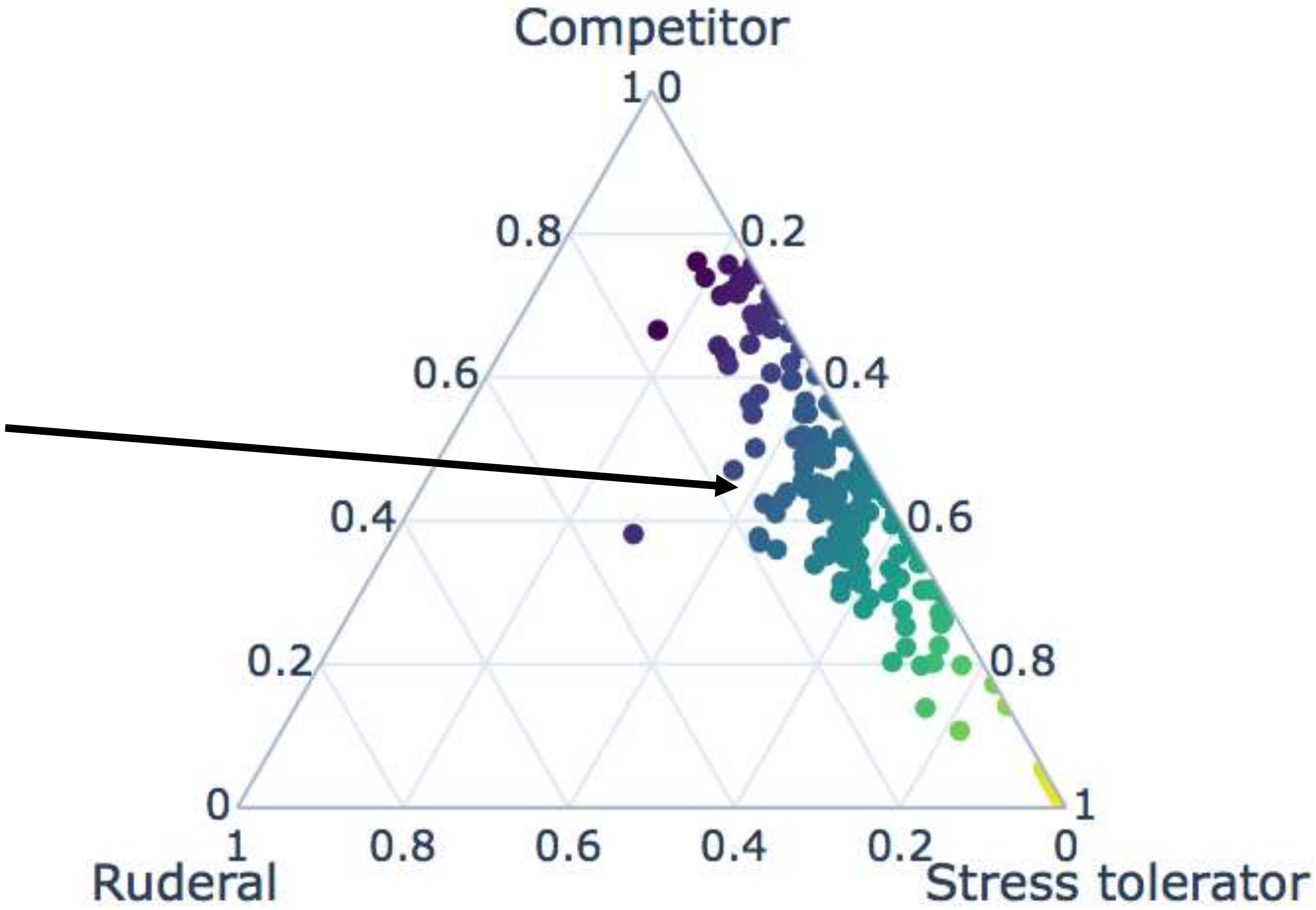



(Sjöman, Hirons and Watkins, 2025)

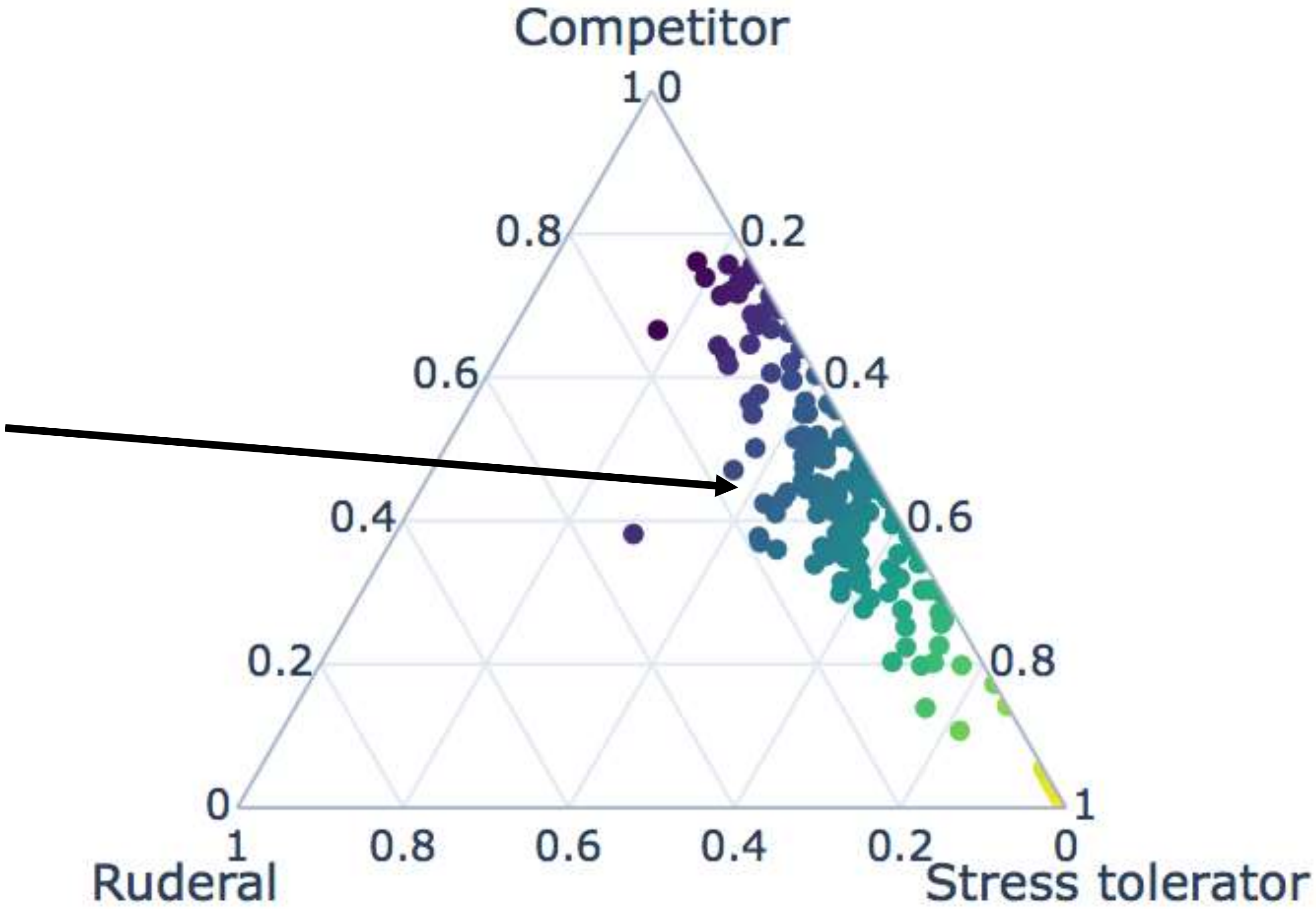

(Sjöman, Hirons and Watkins, 2025)



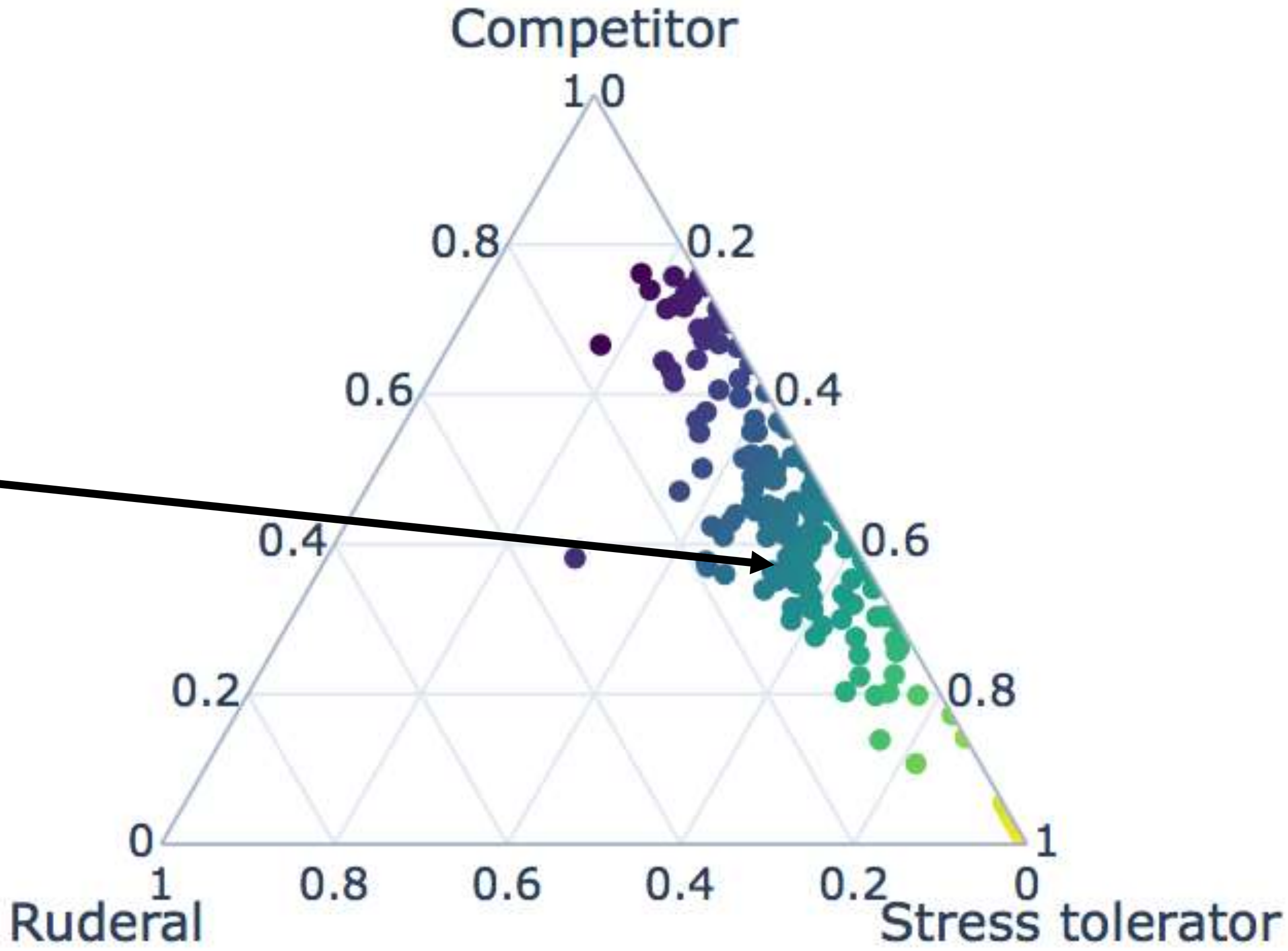



(Sjöman, Hirons and Watkins, 2025)



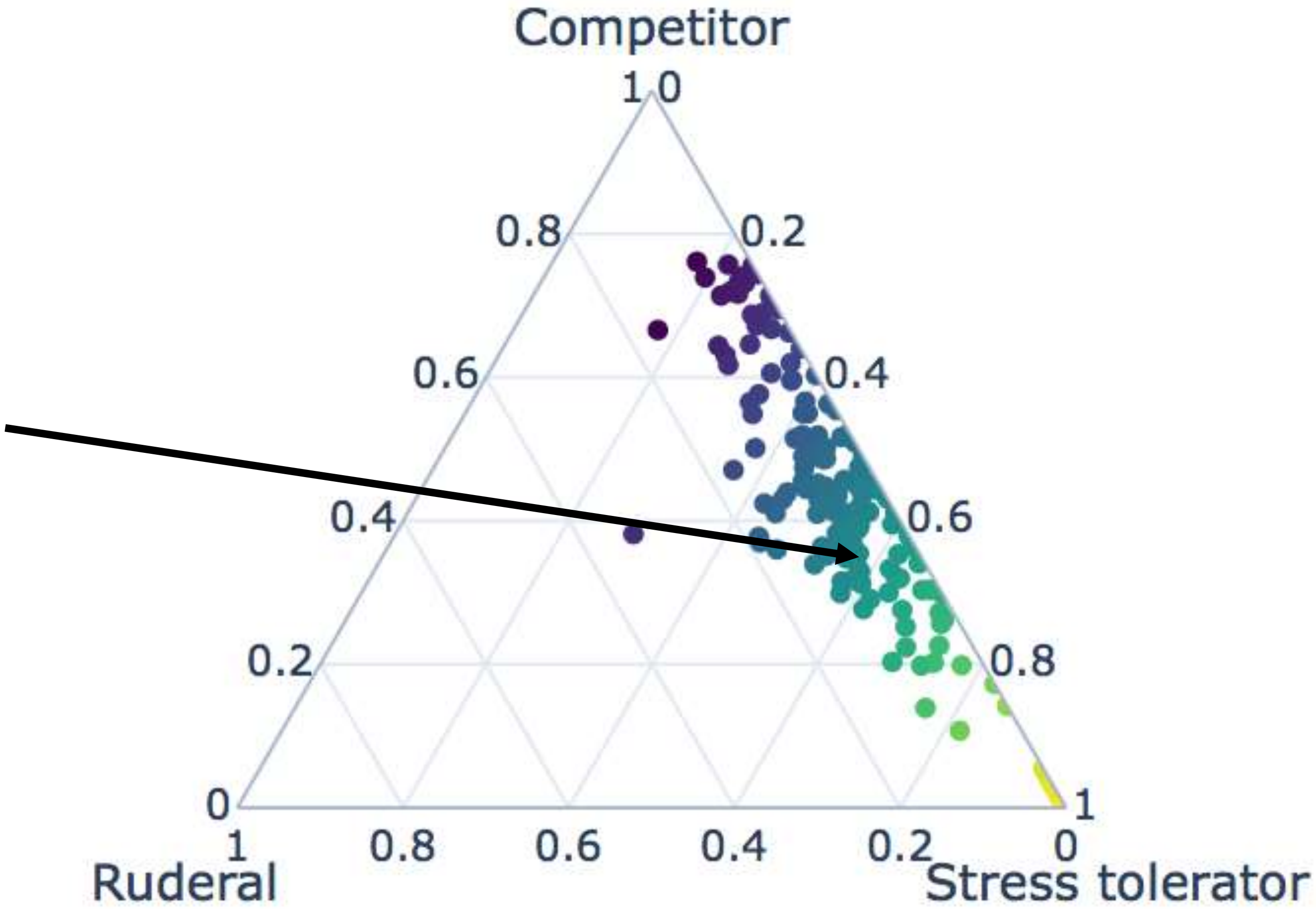



(Sjöman, Hirons and Watkins, 2025)

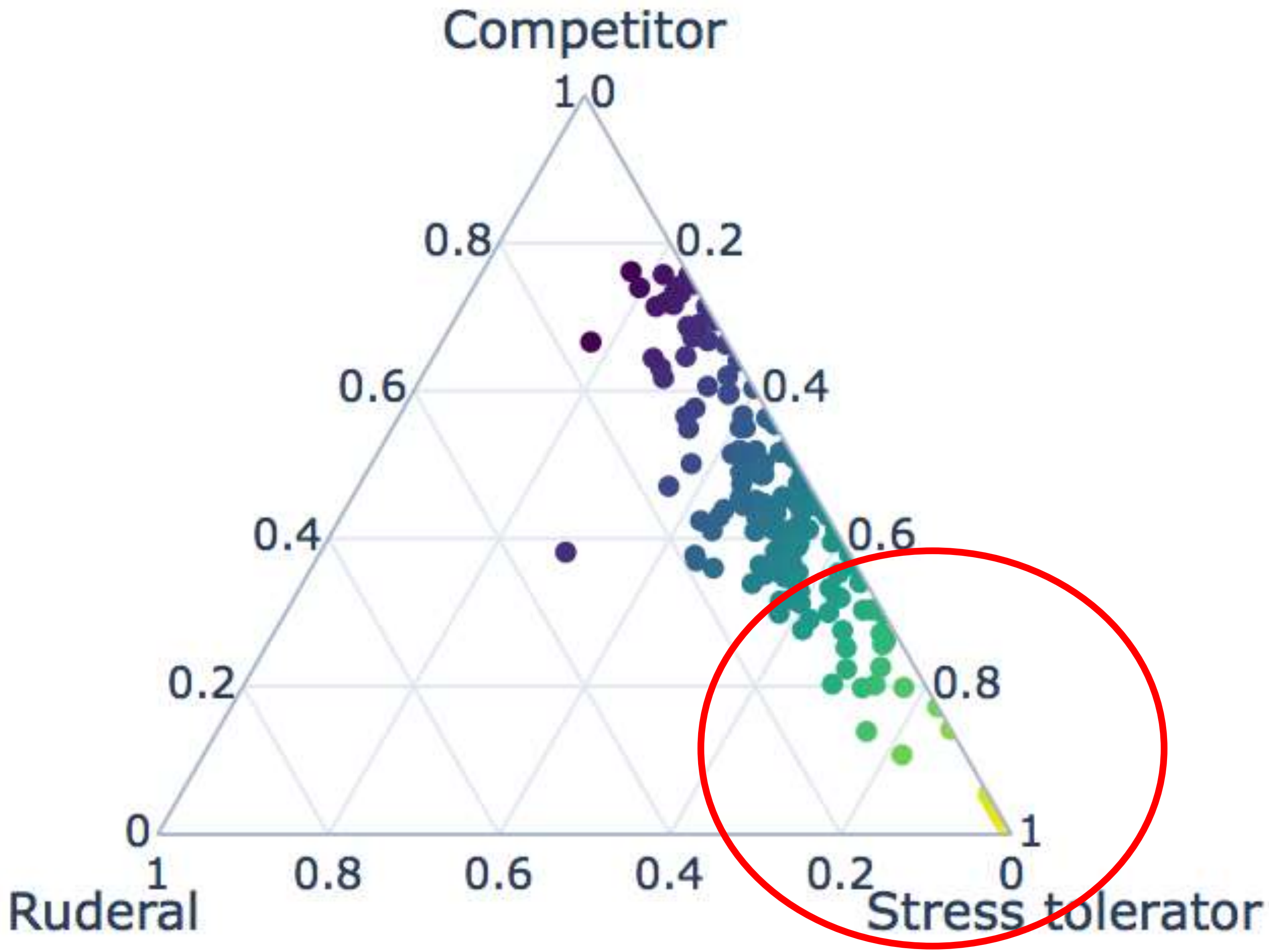

(Sjöman, Hirons and Watkins, 2025)





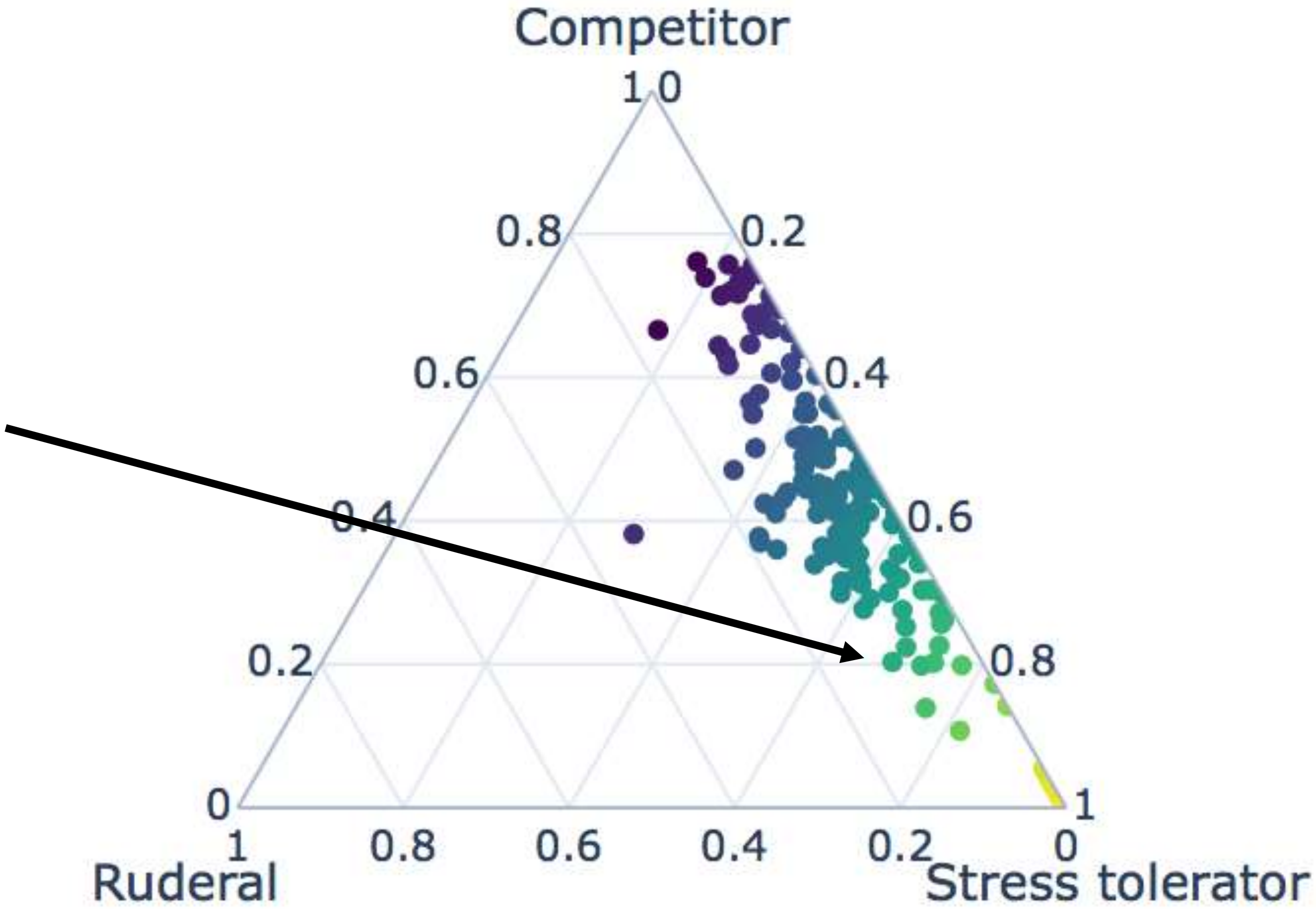

(Sjöman, Hirons and Watkins, 2025)

# CSR ordination of species growing in Alnarp arboretum

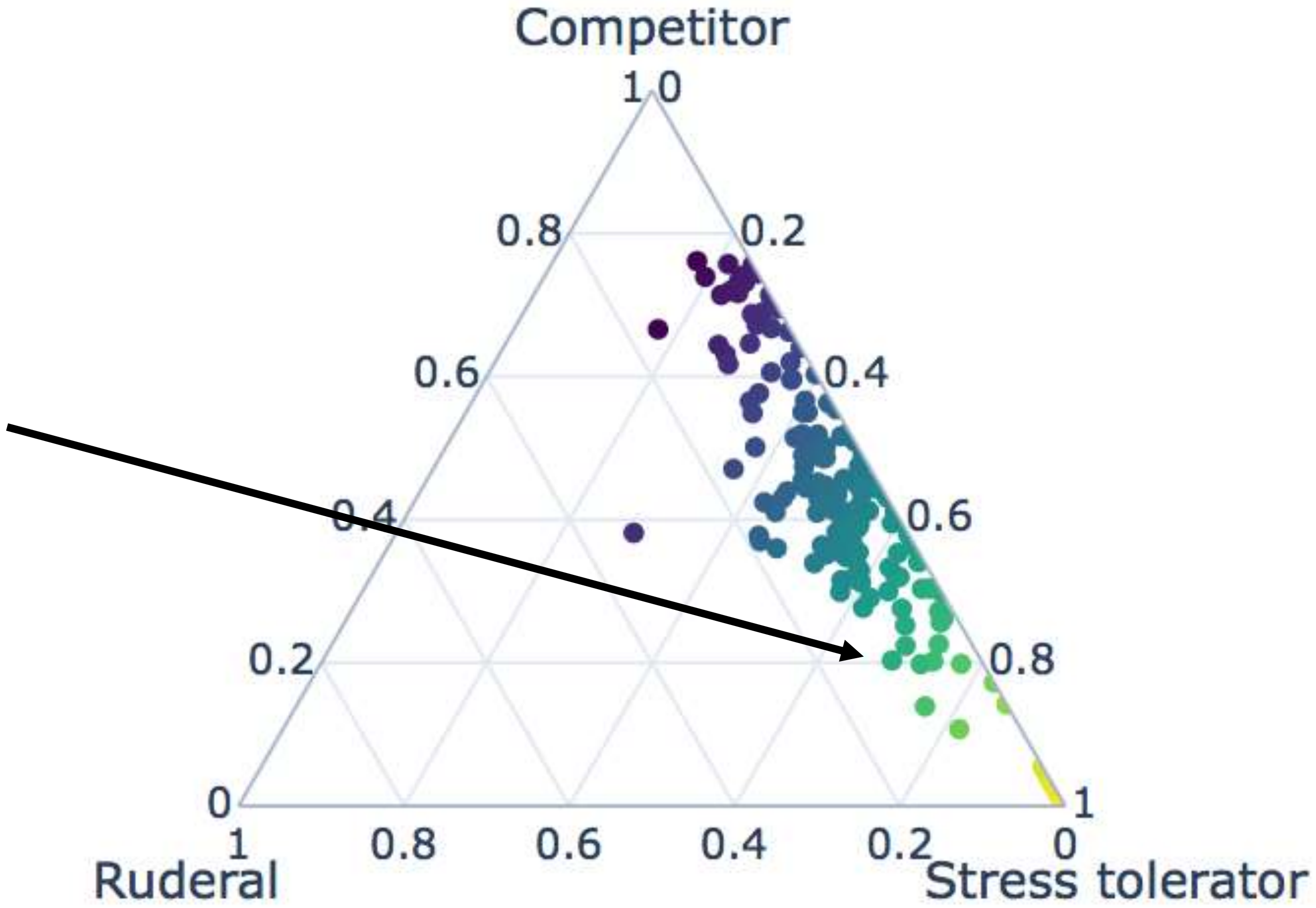



(Sjöman, Hirons and Watkins, 2025)

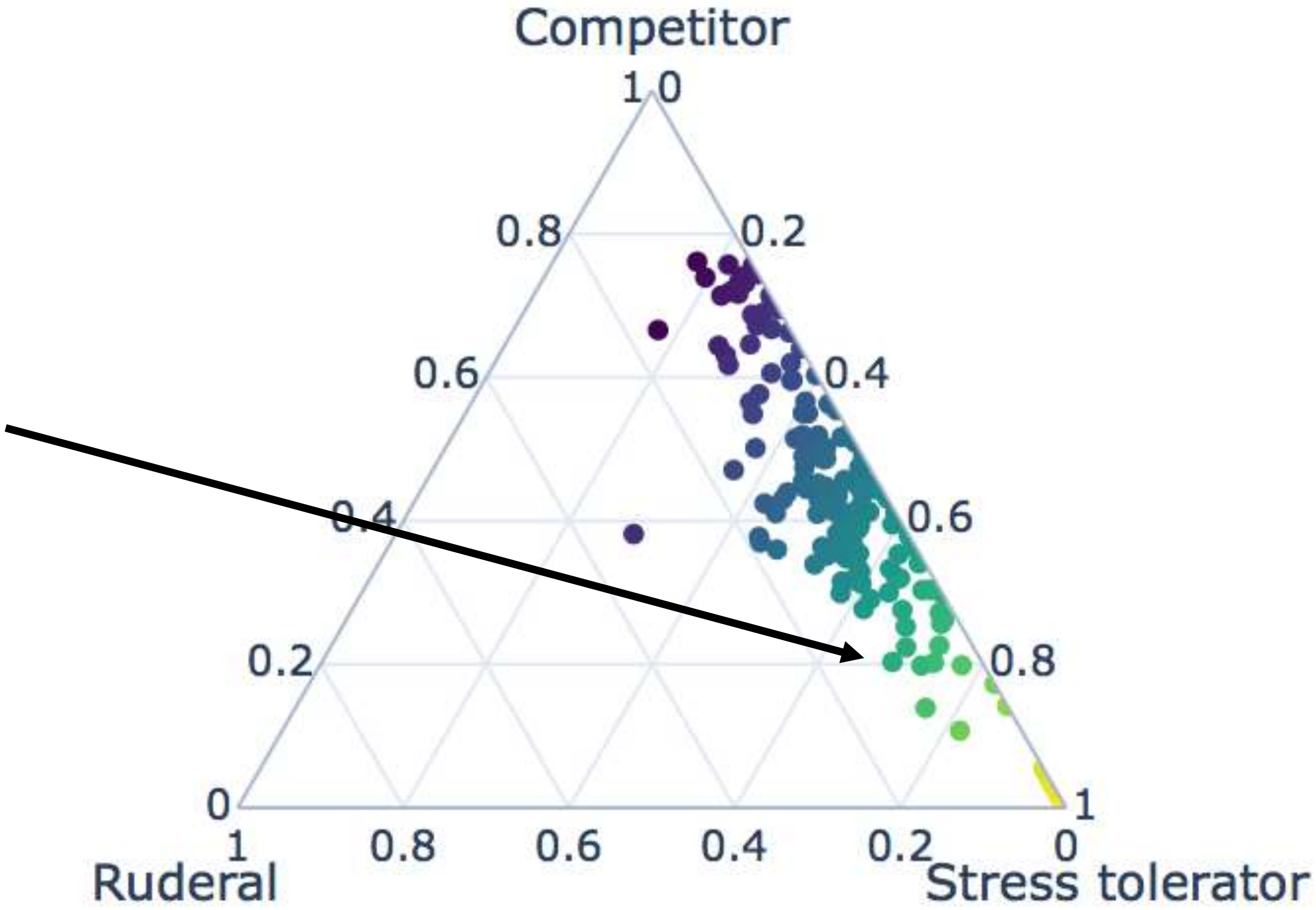





(Sjöman, Hirons and Watkins, 2025)

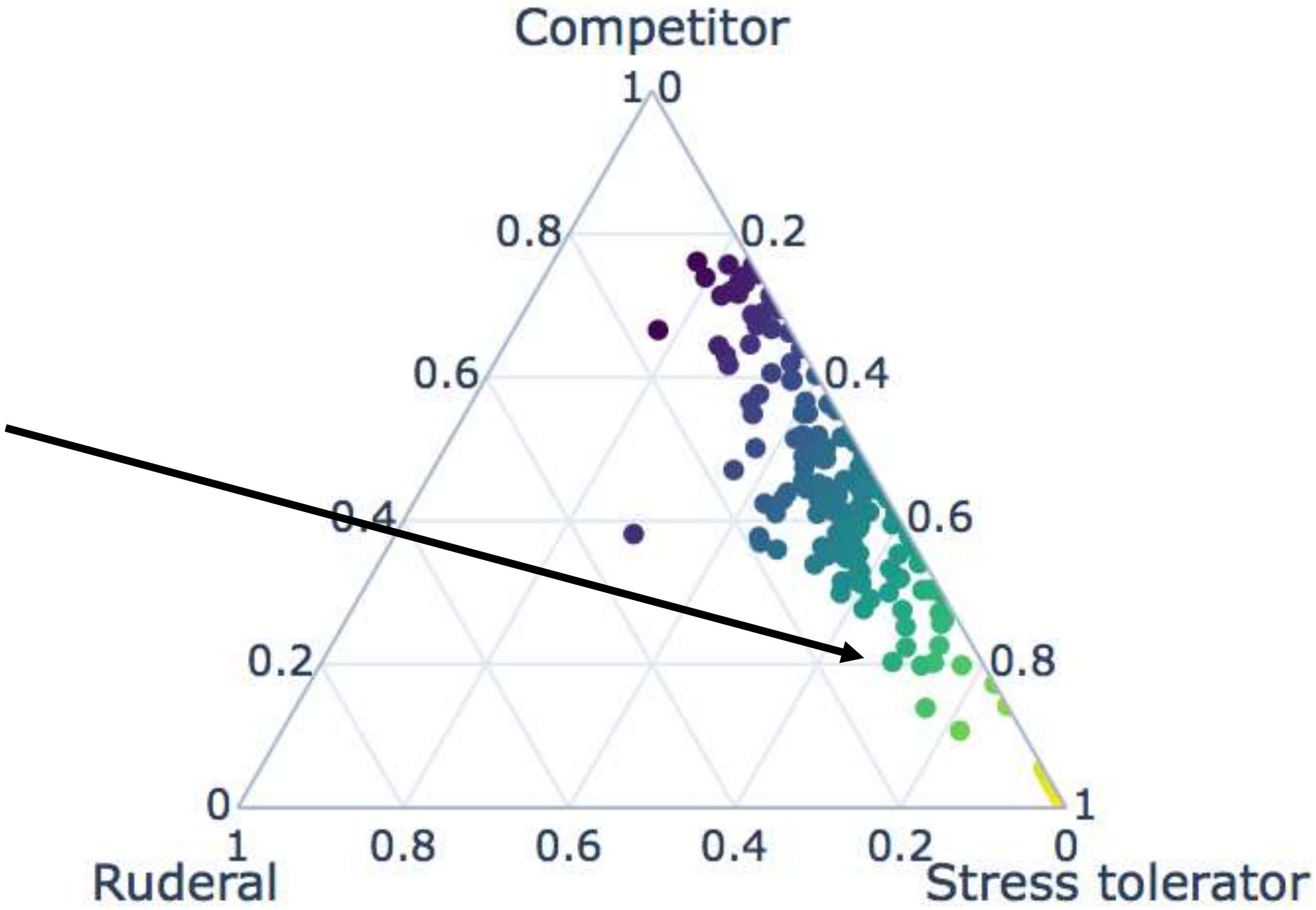




(Sjöman, Hirons and Watkins, 2025)

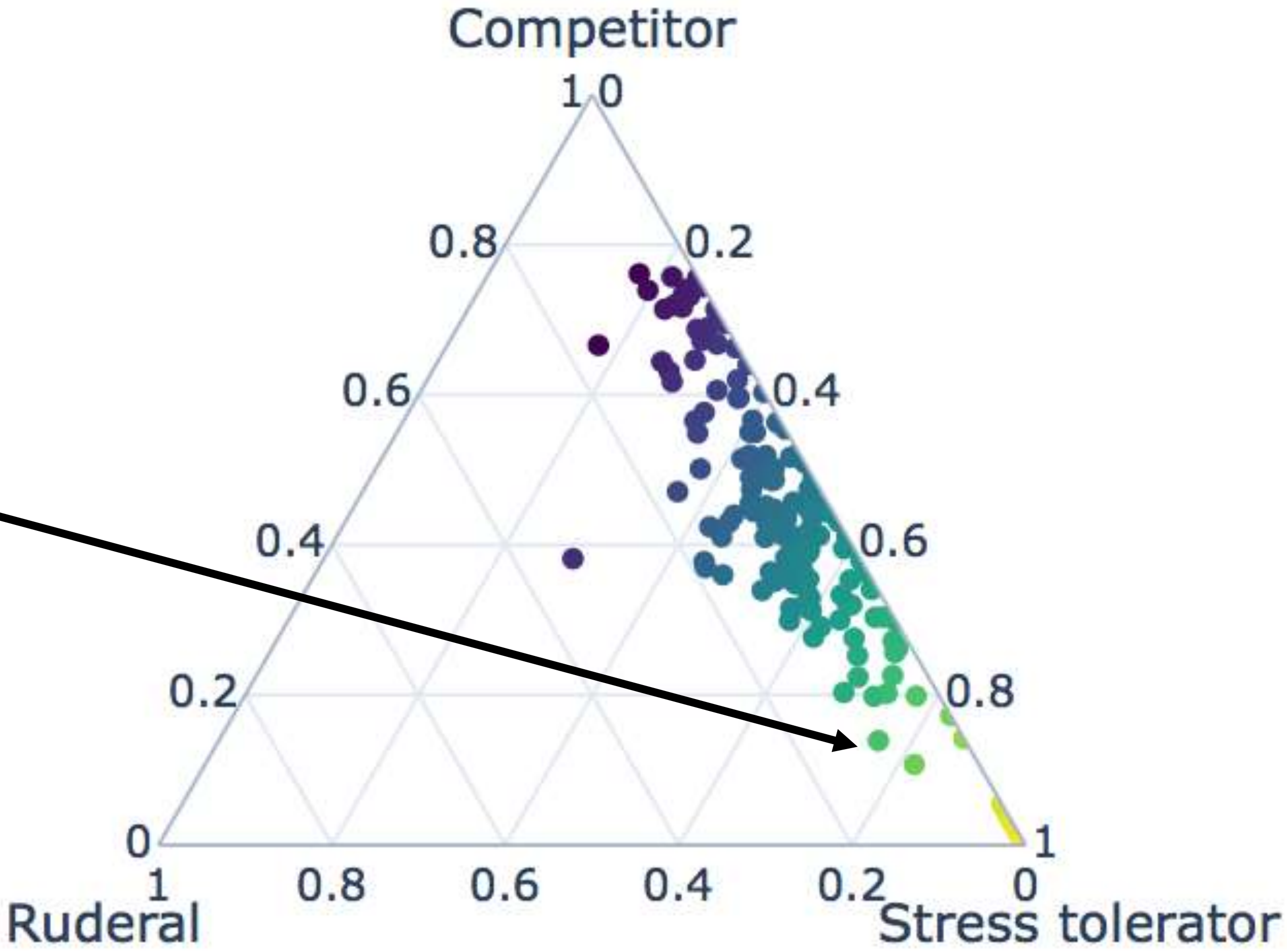

(Sjöman, Hirons and Watkins, 2025)



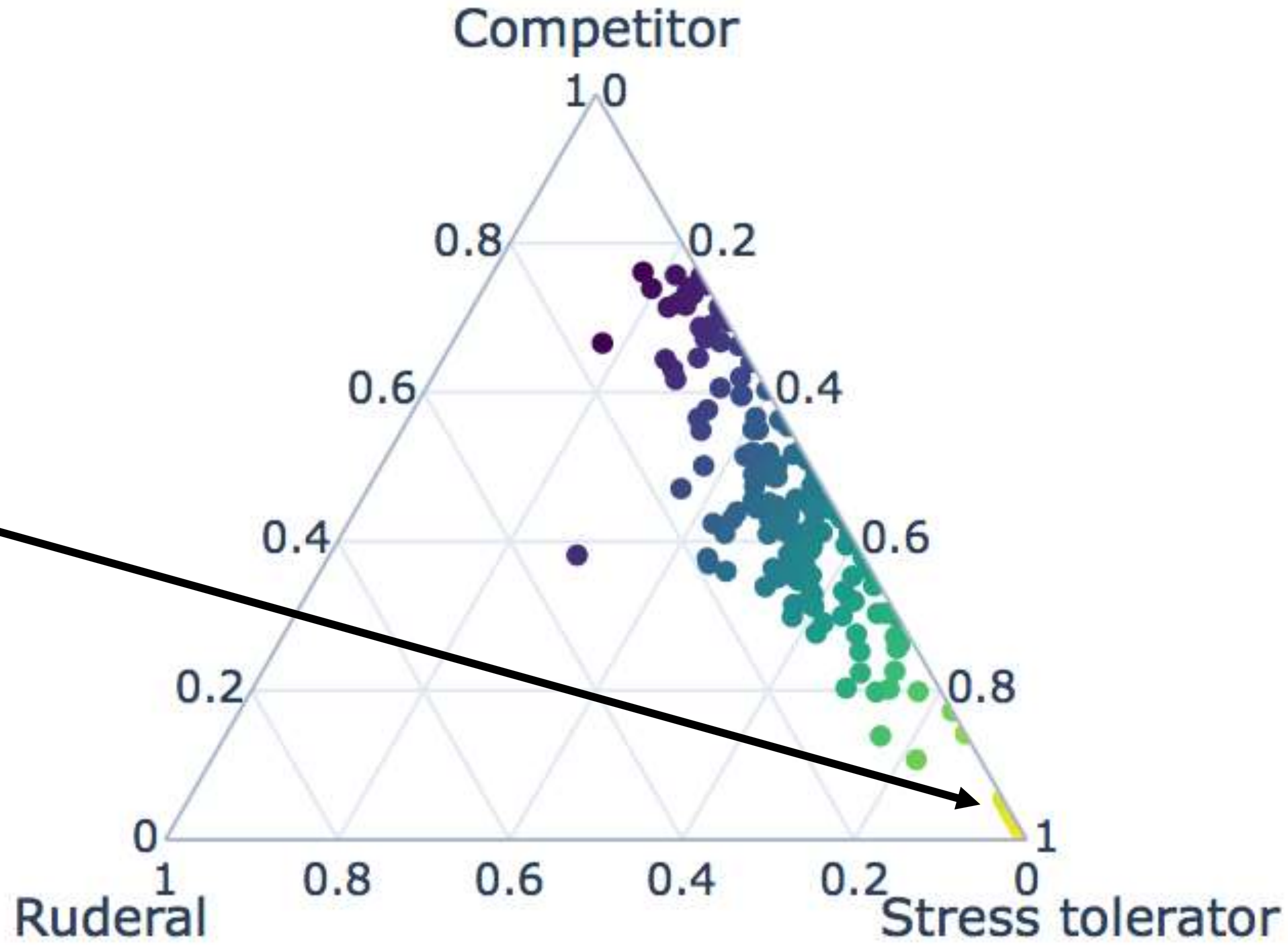



(Sjöman, Hirons and Watkins, 2025)



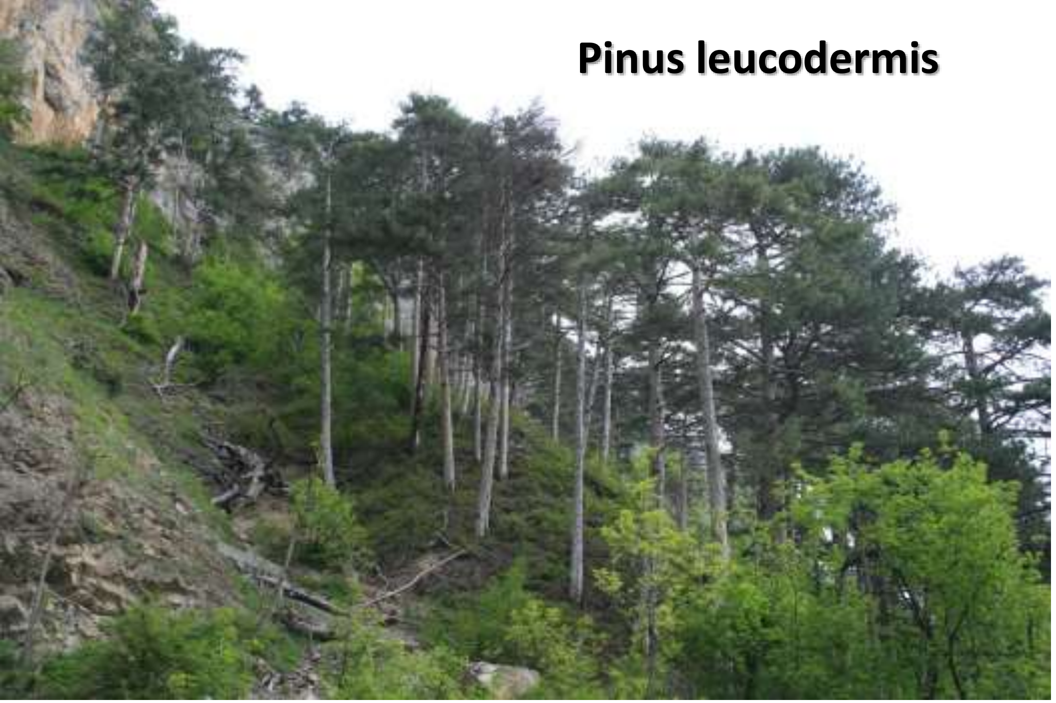


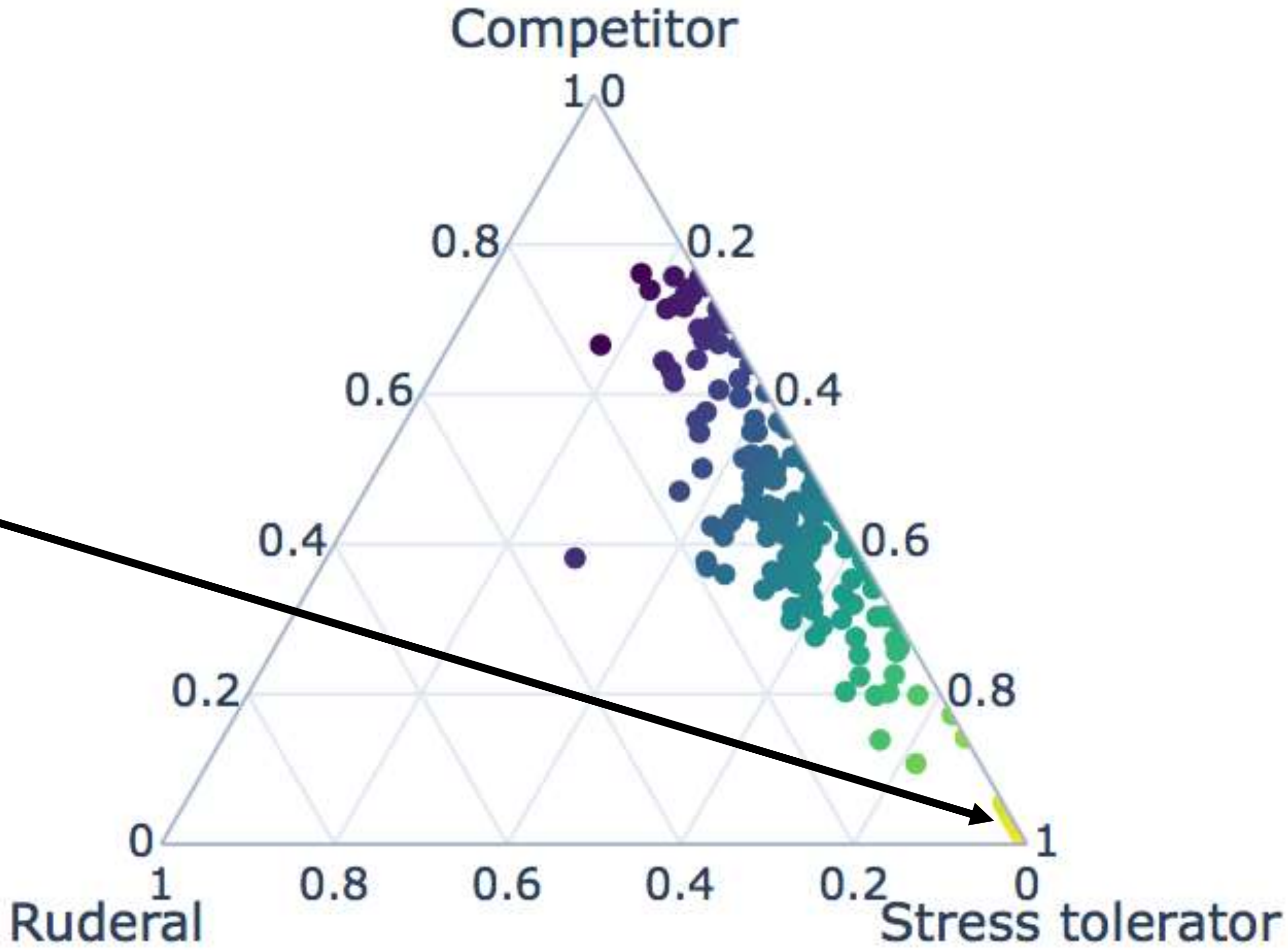

(Sjöman, Hirons and Watkins, 2025)



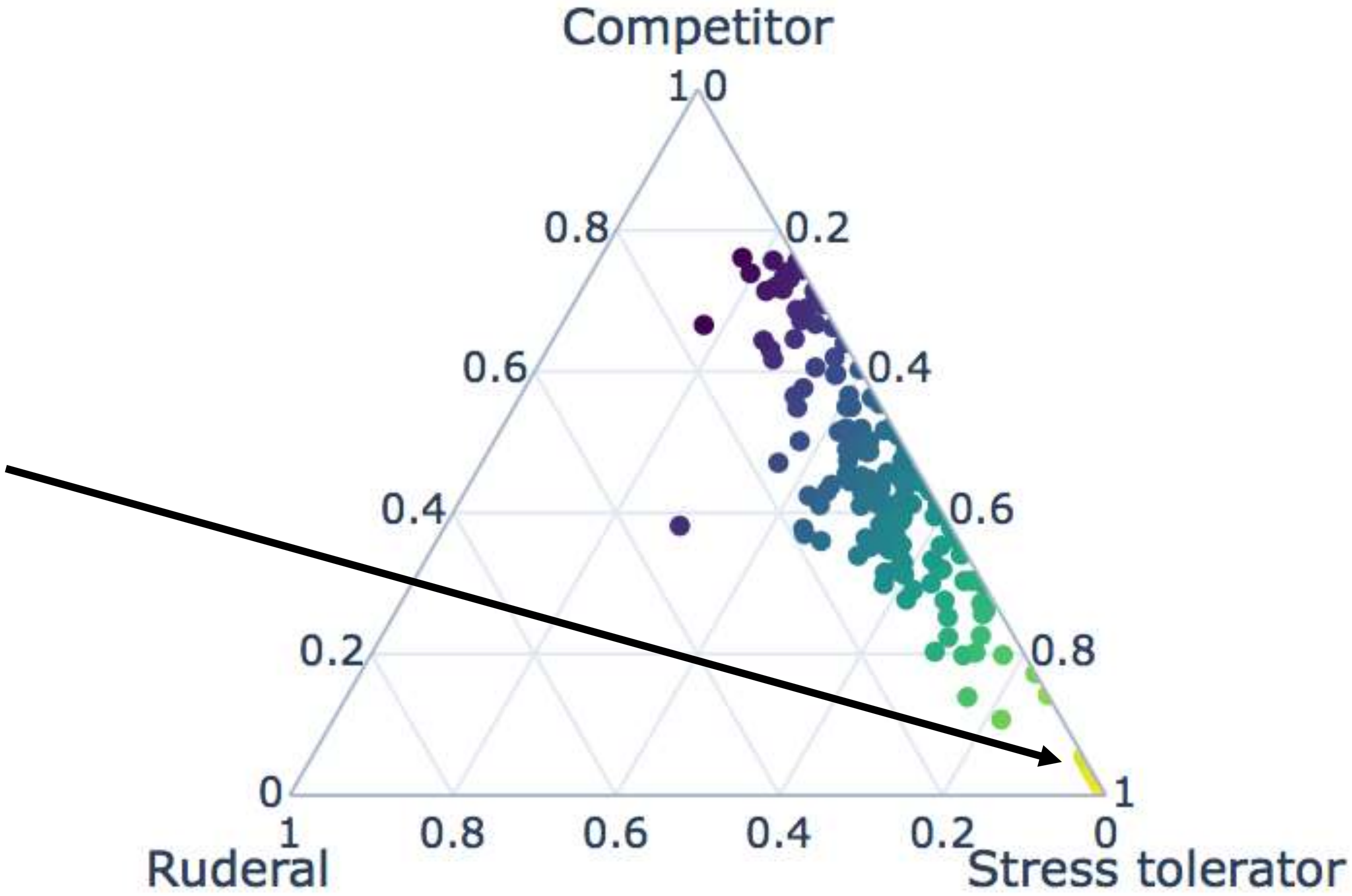

(Sjöman, Hirons and Watkins, 2025)

**Pinus leucodermis**

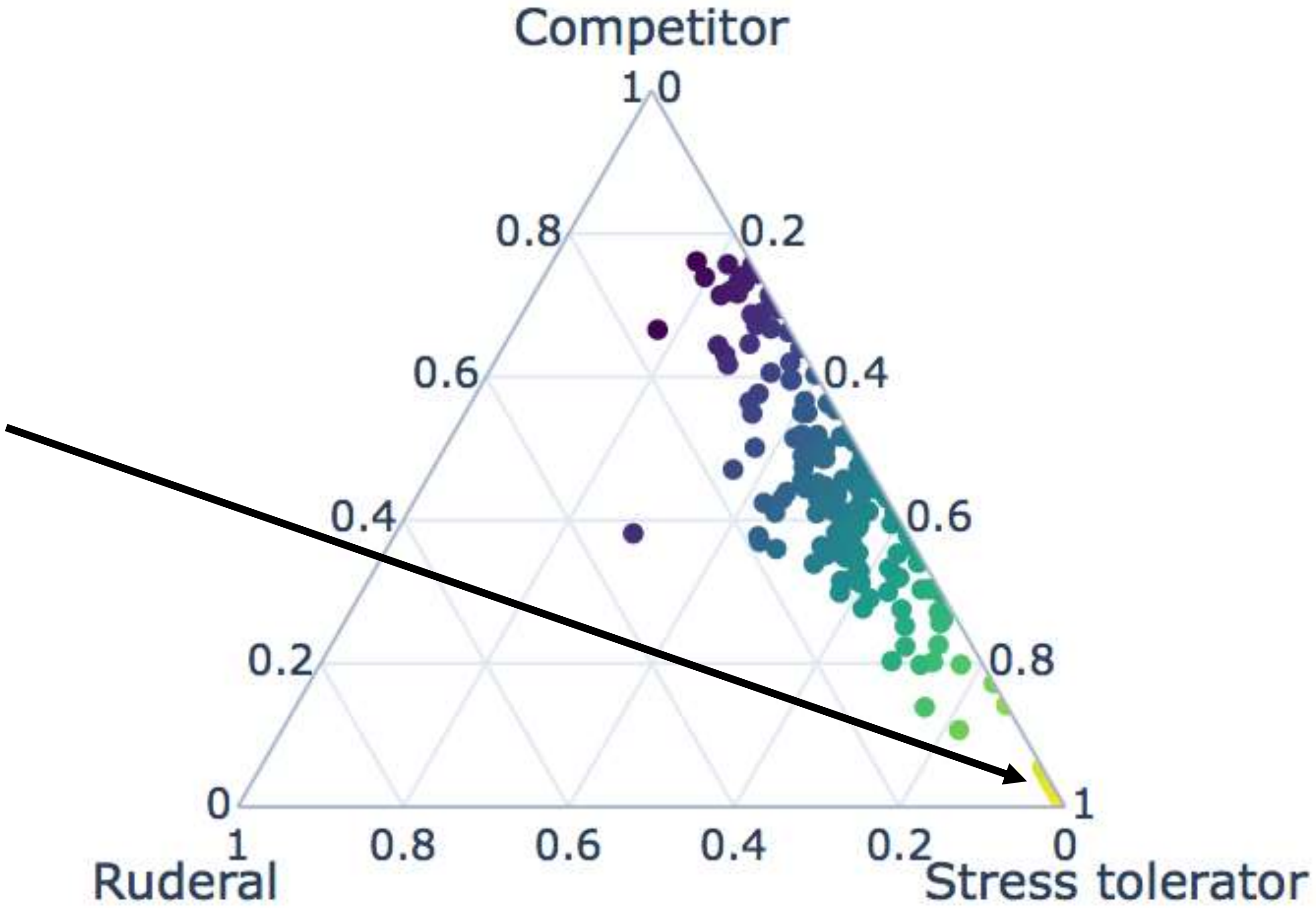



(Sjöman, Hirons and Watkins, 2025)

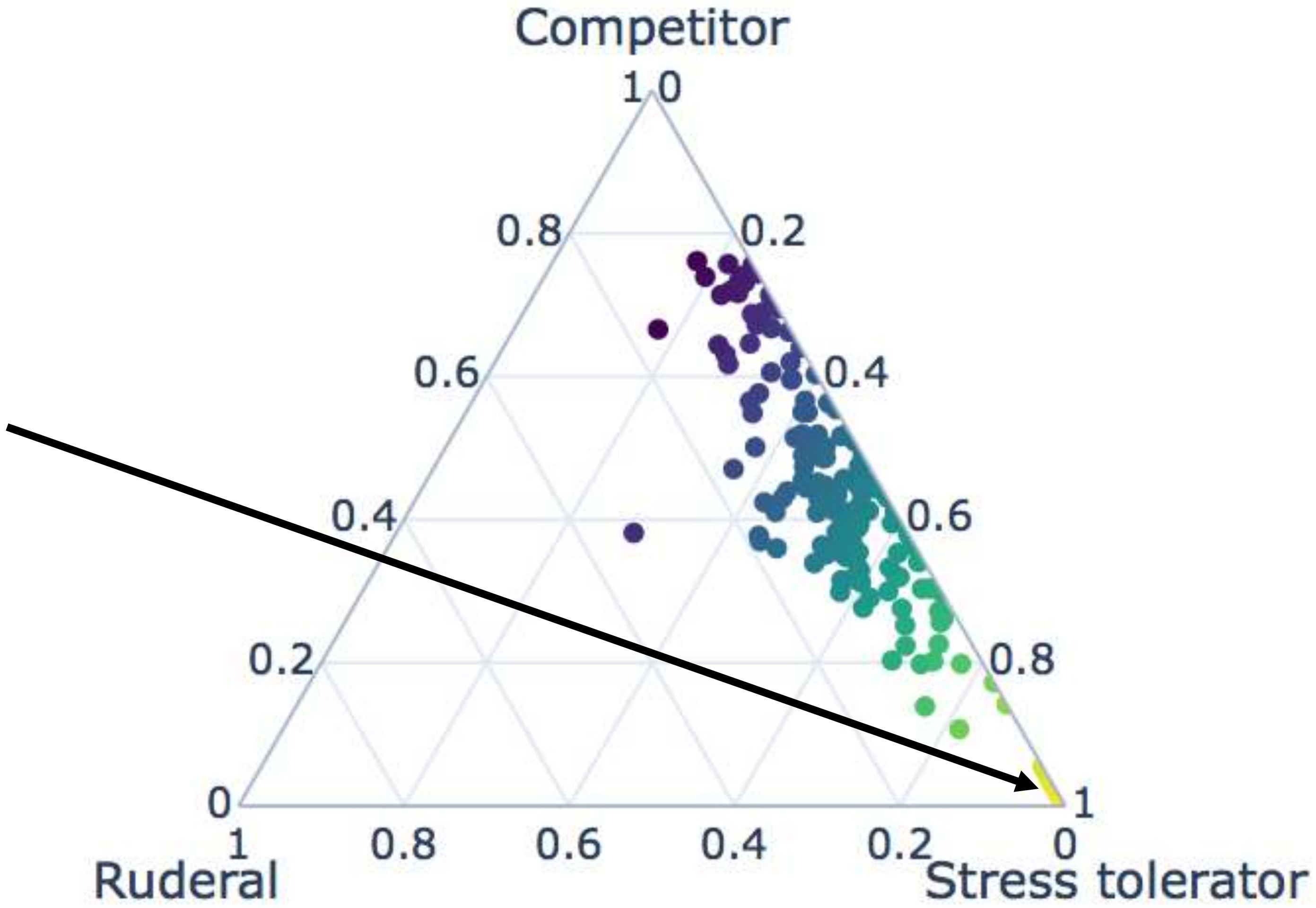




(Sjöman, Hirons and Watkins, 2025)

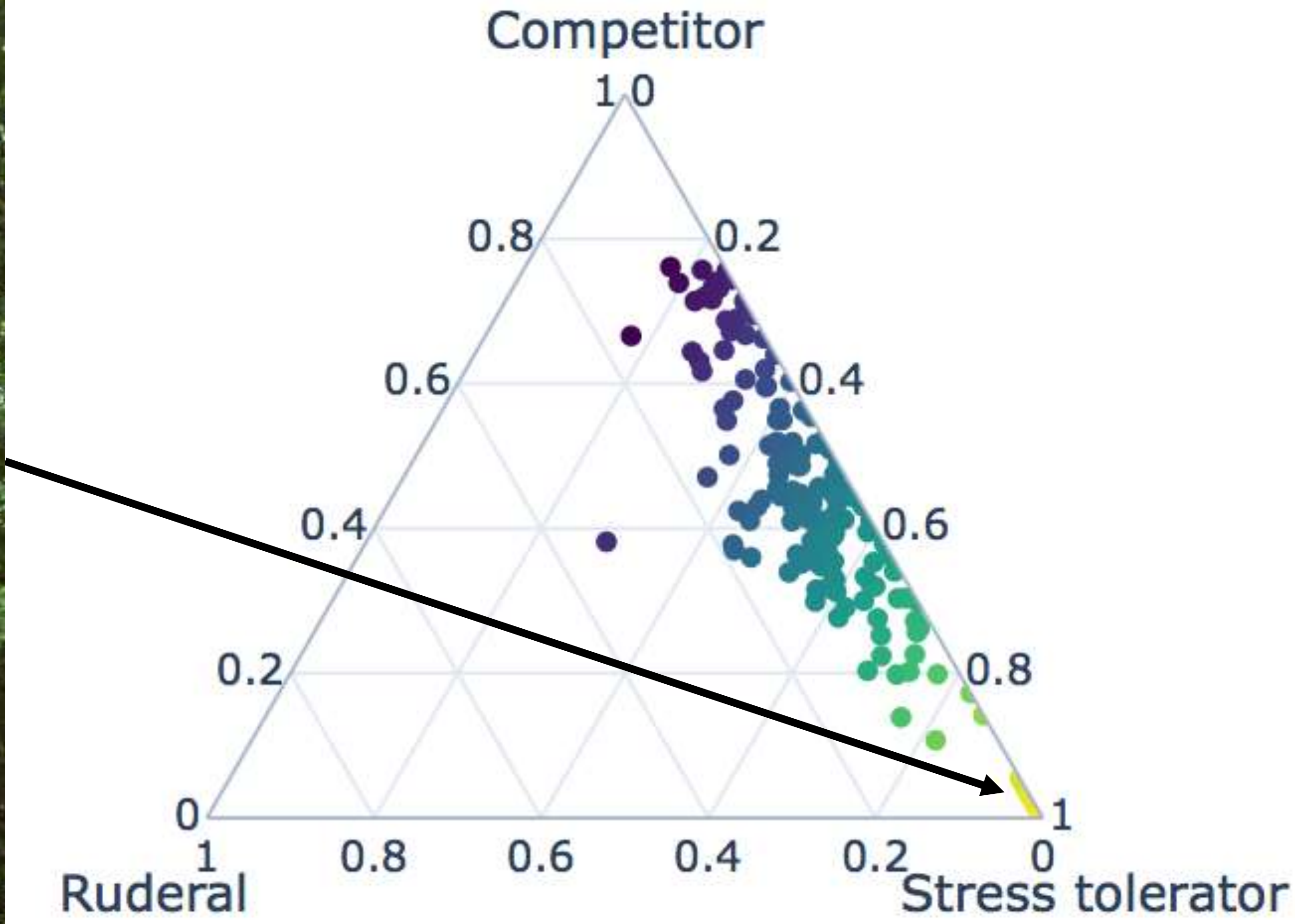




(Sjöman, Hirons and Watkins, 2025)





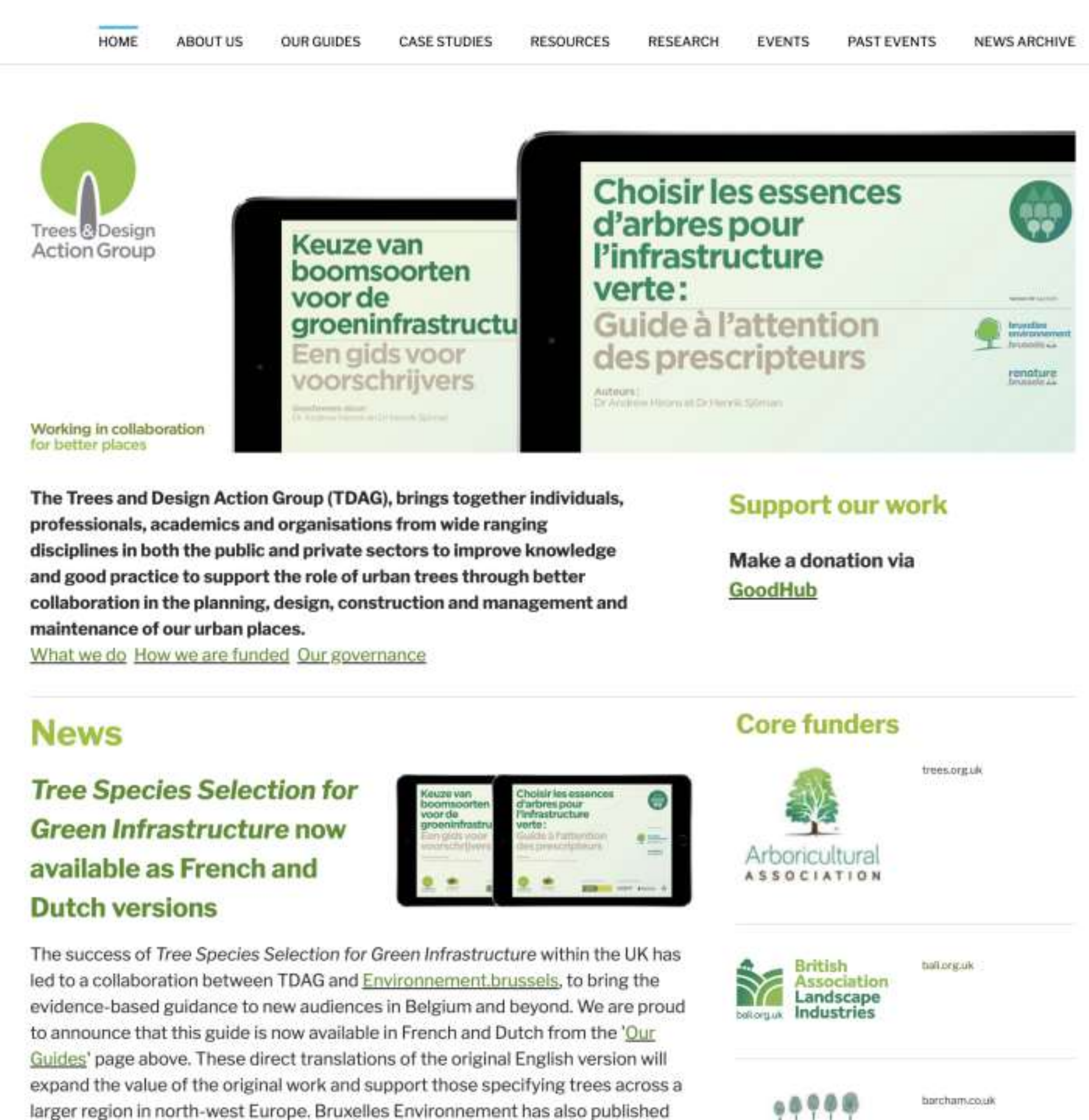

(Sjöman, Hirons and Watkins, 2025)


(Sjöman, Hirons 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.

HOME ABOUT US OUR GUIDES CASE STUDIES RESOURCES RESEARCH EVENTS PAST EVENTS NEWS ARCHIVE

Trees & Design Action Group

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.**

What we do How we are funded Our governance

## Support our work

**Make a donation via GoodHub**

## 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

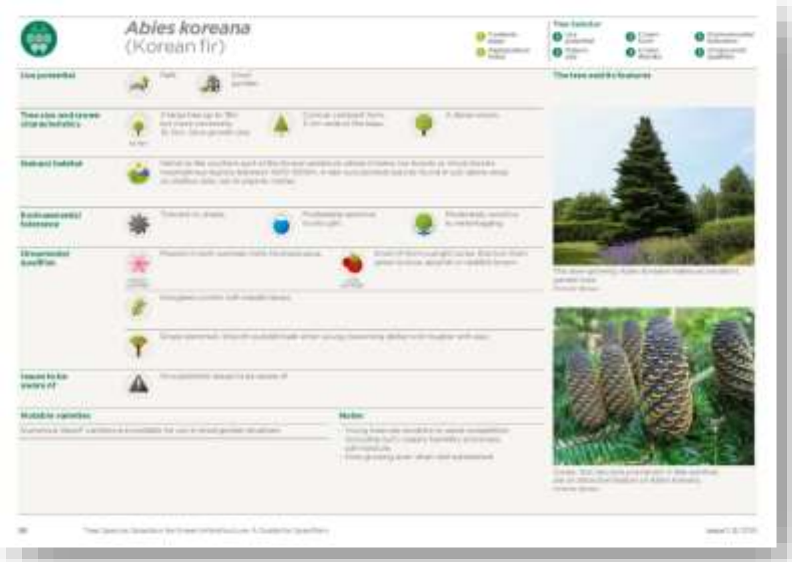
## Core funders

Arboricultural Association — trees.org.uk

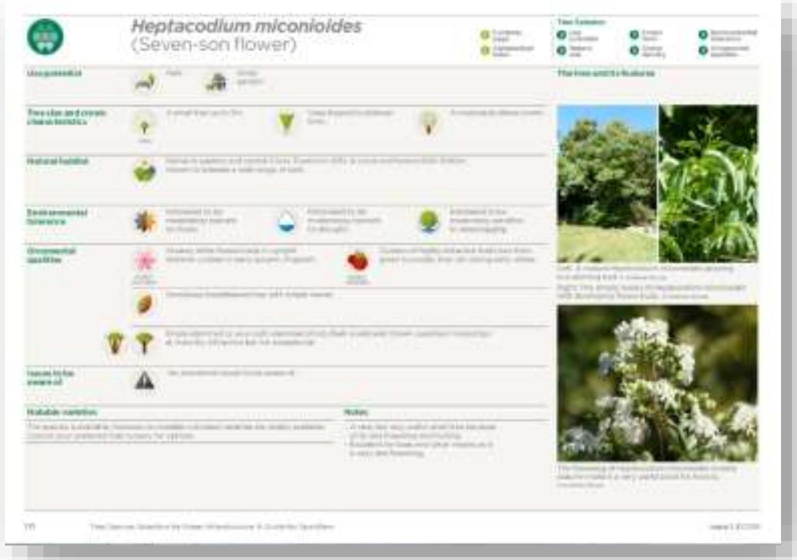
British Association Landscape Industries — bali.org.uk

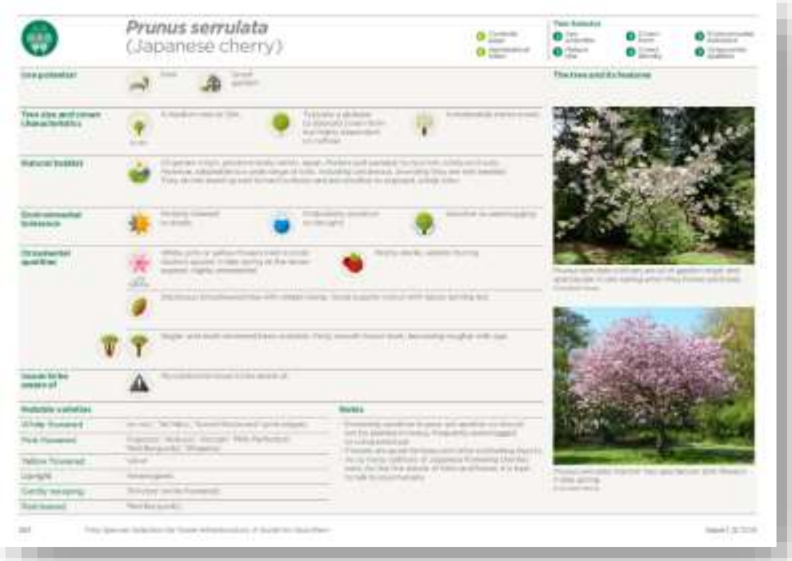
barcham.co.uk

# The profiles (280+)

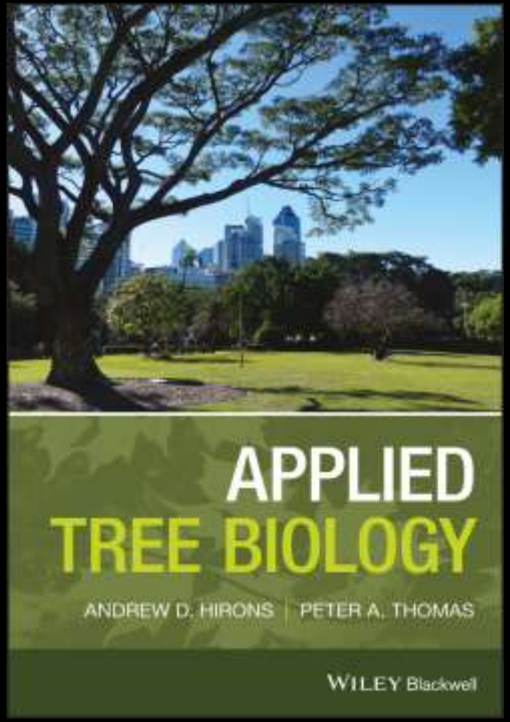





# Thanks for listening




University Centre Myerscough

URBAN PLANT LAB

ahirons@myerscough.ac.uk