Two herbaceous plants and their root systems' association to phenology and weather across botanical gardens

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Introduction

Salvia nemorosa, n = 20

Sanguisorba minor, n = 19

Root growth is severely understudied due to challenges in root investigation (Freschet et al. 2021), as are the influence of abiotic factors such as weather on root formation, and the (a)synchrony of plant development above and below the ground.

As part of the PhenObs project (iDiv 2024), four European botanical gardens harboured plants from the same original populations under similar conditions. Standardised monitoring of phenology (Nordt et al. 2021) for four years was followed by a root harvest at the end of 2023.

Objectives & Methods

Research questions

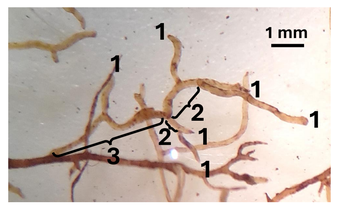
1. What are defining characteristics of the root systems of *Salvia nemorosa* and *Sanguisorba minor* in the botanical gardens in Berlin, Halle, Jena, and Vienna?
2. How do root traits relate to the weather and aboveground phenology across the different sites and years?

Methods

- Root harvest, scanning, and analysis using RhizoVision Explorer (Seethepalli & York 2021)
- Phenology data retrieval from PhenObs
- Weather data retrieval from DWD Climate Data Center (2024) and GeoSphere Austria data hub (2024)
- Exploratory data analysis for differences and correlations between traits, species, and gardens

Table 1 Overview of variables used for calculations

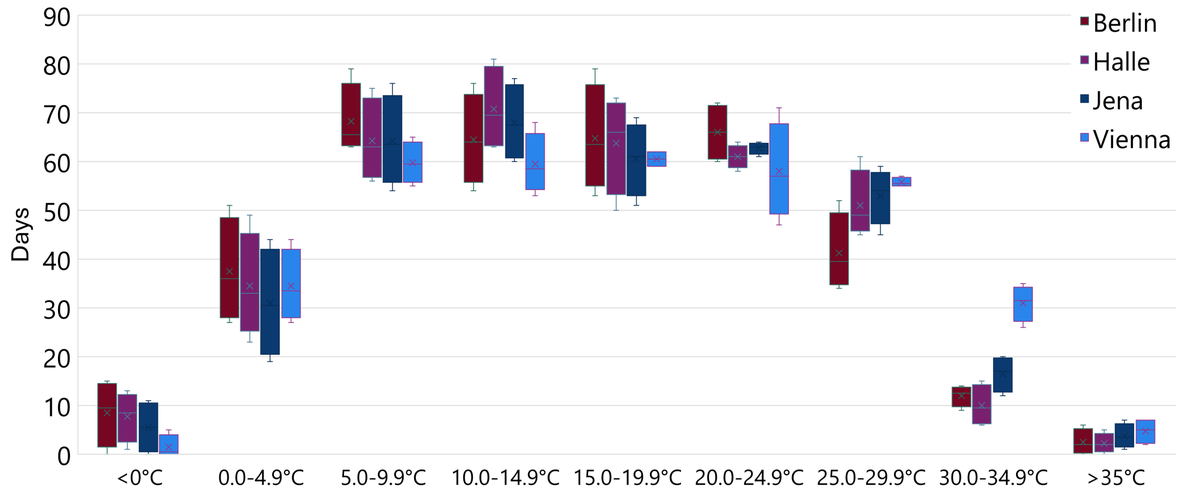
		Variable name	Abbr.	Unit
Roots	N = 39	Root dry matter content	RDMC	mg/mg
		Root tissue density	RTD	mg/mm^3
		Specific root length	SRL	mm/mg
		Root branching density	RBD	mm^{-1}
		Diameter (average, maximum)	Davg, Dmax	mm
		Specific root area	SRA	mm^2/mg
		Number of root tips per dry weight	NRT/DW	mg^{-1}
Weather	2020-2023	Average daily temperature	Tavg	°C
		Averages of maximum daily temperatures	Tmax	°C
		Numbers of days with maximum daily temperature within a 5°C interval		days/year
		Precipitation	PRCP	mm
		Number of days without precipitation	DWP total/year	days/year
		Longest streak of days without precipitation	DWP	
		Average relative humidity	RH	%
		Average vapor pressure	VP	hPa
Phenology	N = 210	Initial growth	IG	day of year
		First leaf	FL	day of year
		First flower	FF	day of year
		Peak flowering	PF	day of year
		End of peak flowering	EPF	day of year
		End of flowering	EF	day of year
		Flowering duration	FD	days
		First fruit	FFr	day of year
		Start of senescence	SS	day of year
		Vegetation period	VP	days
		50% senescence	S50	day of year



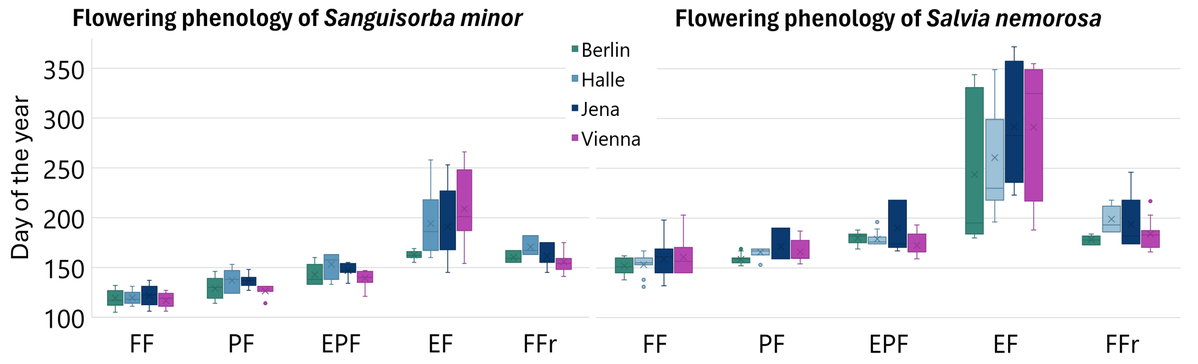
Segment-based root classification and selection of order 1, 2, and 3 fine roots

Results

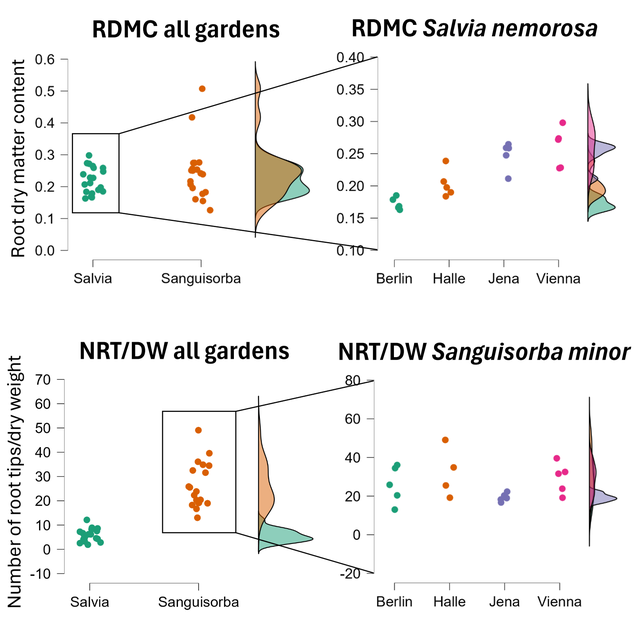
Weather



Plant phenology



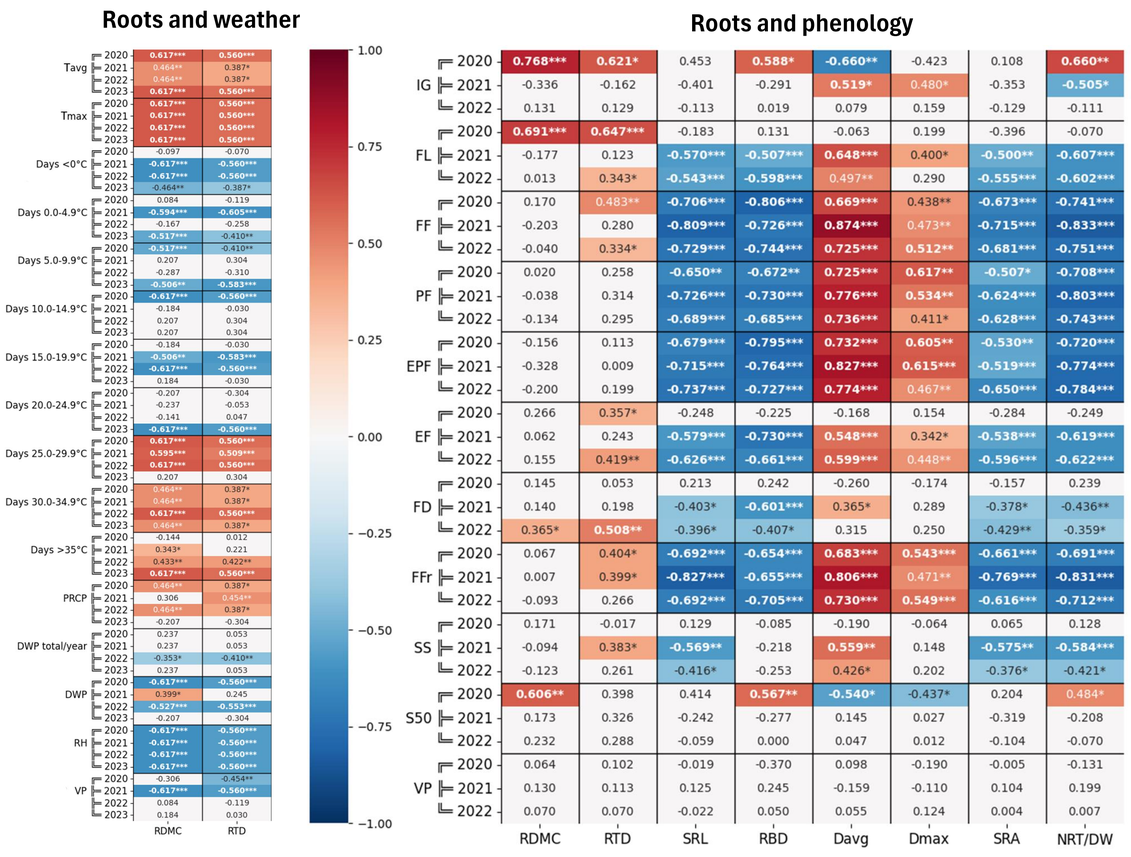
Roots



Root mass correlates with weather. Root length, branching density, diameter, area, and root tips correlate with plant phenology.

Most weather variables differ ($p<0.006$) between the gardens.
Phenology data are most complete for FF to SS, and the majority of traits (except FL, FF, and EPF) differ ($p<0.037$) between the gardens.
RDMC and RTD for *Salvia nemorosa*, and Davg for *Sanguisorba minor* differ between locations ($p<0.022$). Other traits differ between species (SRL, RBD, Davg, Dmax, SRA, NRT/DW, $p<0.001$) but not between gardens.
Spearman's rank for all phenology and weather variables with all root variables suggests a correlation pattern of RDMC and RTD with weather variables, while SRL, RBD, Davg and Dmax, SRA, and NRT/DW seem more tightly linked to (reproductive) phenology.

Correlations



Conclusion

For both species, the most characteristic root trait showing the least dispersion and variation between gardens is the root branching density.
Significant differences in weather conditions and aboveground plant development across the gardens allow a calculation of links between weather, phenology, and root morphology and growth. For the association of phenology and roots, the direction of influence remains a promising subject of future research.
The phenological development and root systems of *Salvia nemorosa* and *Sanguisorba minor* differ considerably. Nevertheless, their root traits' correlations with phenology and weather underline the importance of understanding all three factors for an overall comprehension of herbaceous plants' development.

References

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PhenOBS Botanical Gardens as a Global Phenological Observation Network

APPN Austrian Plant Phenotyping Network