

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

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## INTRODUCTION



*Salvia nemorosa*, n = 20    *Sangisorba 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

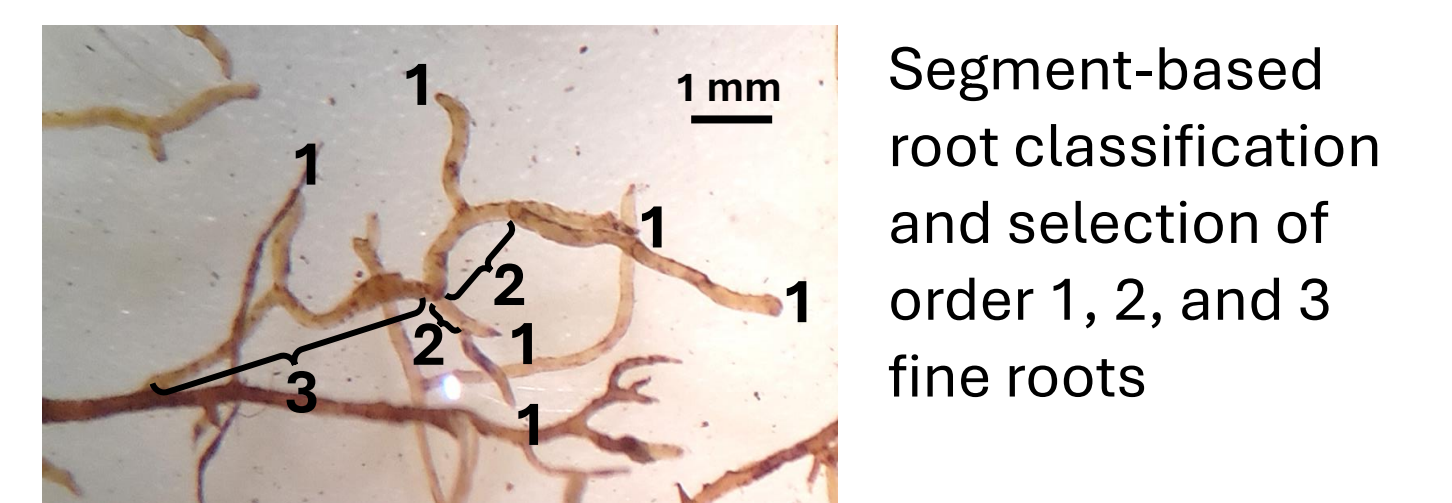
1. What are defining characteristics of the root systems of *Salvia nemorosa* and *Sangisorba minor* in the botanical gardens in Berlin, Halle, Jena, and Vienna?
2. How do root traits relate to the weather and aboveground phenology across the different sites and years?

### 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

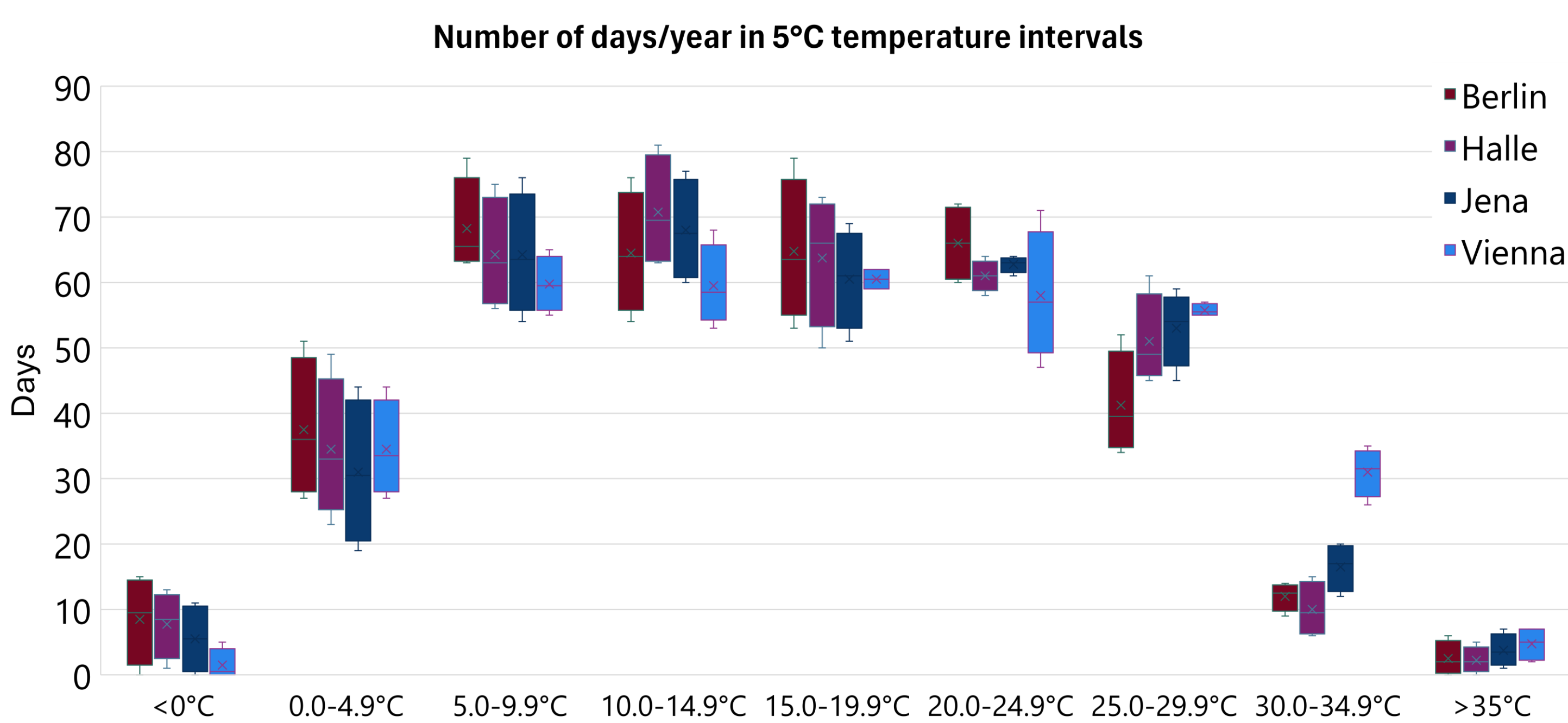
	Variable name	Abbr.	Unit
Roots	Root dry matter content	RDMC	mg/mg
	Root tissue density	RTD	mg/mm <sup>3</sup>
	Specific root length	SRL	mm/mg
	Root branching density	RBD	mm <sup>3</sup>
	Diameter (average, maximum)	Davg, Dmax	mm
	Specific root area	SRA	mm <sup>2</sup> /mg
	Number of root tips per dry weight	NRT/DW	mg <sup>-1</sup>
Weather	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	days
	Average relative humidity	RH	%
Phenology	Average vapor pressure	VP	hPa
	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	



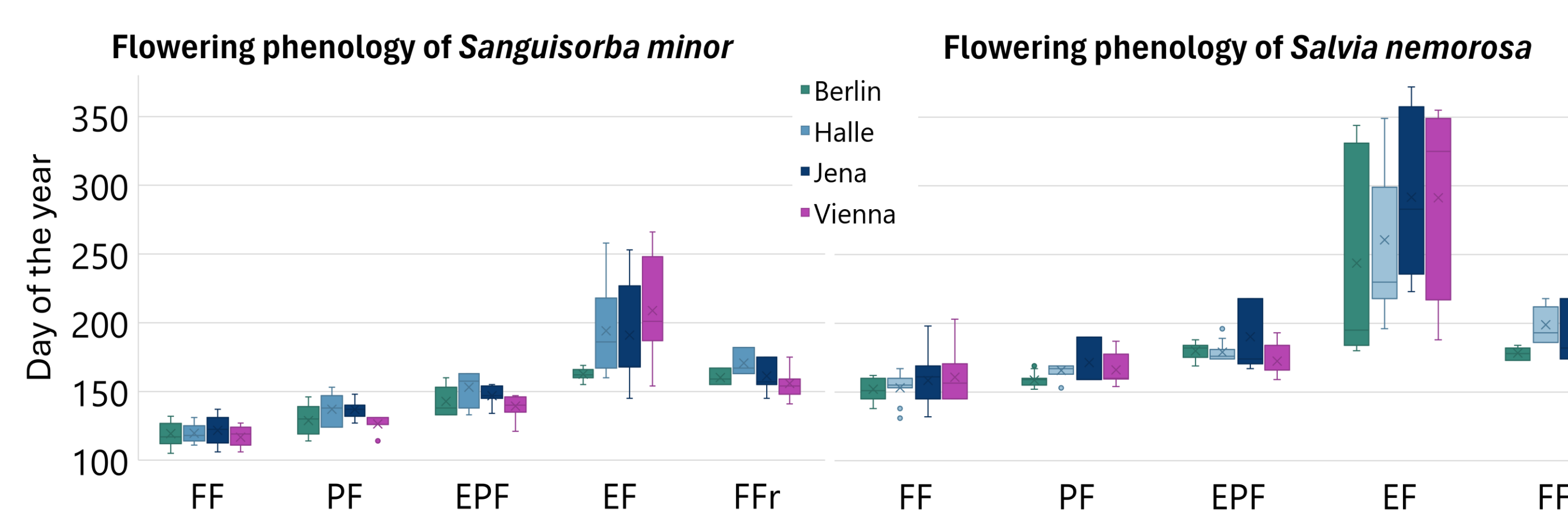
Segment-based root classification and selection of order 1, 2, and 3 fine roots

## RESULTS

### Weather



### Plant phenology



### Correlations

#### Roots and weather

	RDMC	RTD
Tavg	0.617***	0.560***
Tmax	0.617***	0.560***
Days <0°C	-0.037	-0.070
Days 0.0-4.9°C	0.004	0.119
Days 5.0-9.9°C	0.310***	0.410***
Days 10.0-14.9°C	0.207	0.304
Days 15.0-19.9°C	0.184	0.030
Days 20.0-24.9°C	0.207	0.304
Days 25.0-29.9°C	0.184	0.030
Days 30.0-34.9°C	0.184	0.030
Days >35°C	0.184	0.030
PRCP	0.106	0.387*
DWP total/year	0.237	0.093
DWP	0.237	0.093
RH	0.237	0.093
VP	0.106	0.387*

#### Roots and phenology

	RDMC	RTD	SRL	RBD	Davg	Dmax	SRA	NRT/DW
IG	0.768***	0.621**	0.453	0.588**	-0.660***	-0.423	0.108	0.660**
FL	0.691***	0.647***	-0.183	0.131	-0.063	0.199	-0.396	-0.070
FF	-0.177	0.123	-0.570***	-0.570***	0.648***	0.400*	-0.500**	-0.607***
PF	0.013	0.343*	-0.543***	-0.598***	0.497**	0.290	-0.555***	-0.602**
EPF	0.170	0.483**	-0.706***	-0.806***	0.669***	0.438**	-0.673***	-0.741***
EF	-0.203	0.280	-0.809***	-0.726***	0.874***	0.473**	-0.715***	-0.833***
FFr	-0.040	0.334*	-0.729***	-0.744***	0.725***	0.512**	-0.681***	-0.751***
SS	0.020	0.258	-0.650***	-0.672**	0.725***	0.617**	-0.507*	-0.708**
S50	-0.038	0.314	-0.726***	-0.730***	0.776***	0.534**	-0.624***	-0.803***
VP	-0.134	0.295	-0.689***	-0.685***	0.736***	0.411*	-0.628**	-0.743***
PRCP	-0.156	0.113	-0.679***	-0.795***	0.732***	0.605**	-0.530**	-0.720***
DWP total/year	-0.328	0.009	-0.715***	-0.764***	0.827***	0.615***	-0.519***	-0.774***
DWP	-0.200	0.199	-0.737***	-0.727***	0.774***	0.467**	-0.650***	-0.784***
RH	0.266	0.357*	-0.248	-0.225	-0.168	0.154	-0.284	-0.249
VP	0.062	0.243	-0.579***	-0.730***	0.548***	0.342*	-0.538***	-0.619***
VP	0.155	0.419**	-0.626***	-0.661***	0.599***	0.448**	-0.596***	-0.622**
VP	0.145	0.053	0.213	0.242	-0.260	-0.174	-0.157	0.239
VP	0.140	0.198	-0.403**	-0.601***	0.365**	0.289	-0.378*	-0.436**
VP	0.365**	0.508**	-0.396*	-0.407*	0.315	0.250	-0.429**	-0.359*
VP	0.067	0.404*	-0.692***	-0.654***	0.683***	0.543***	-0.661***	-0.691***
VP	0.007	0.399*	-0.827***	-0.655***	0.806***	0.471**	-0.769***	-0.831***
VP	-0.093	0.266	-0.692***	-0.705***	0.730***	0.549***	-0.616***	-0.712***
VP	0.171	-0.017	0.129	-0.085	-0.190	-0.064	0.065	0.128
VP	-0.094	0.383*	-0.569**	-0.218	0.559**	0.148	-0.575**	-0.584**
VP	-0.123	0.261	-0.416*	-0.253	0.426*	0.202	-0.376*	-0.421*
VP	0.606**	0.398	0.414	0.567**	-0.540*	-0.437*	0.204	-0.465*
VP	0.173	0.326	-0.242	-0.277	0.145	0.027	-0.319	-0.208
VP	0.232	0.288	-0.059	-0.000	0.047	0.012	-0.104	-0.070
VP	0.064	0.102	-0.019	-0.370	0.098	-0.190	-0.005	-0.131
VP	0.130	0.113	0.125	0.245	-0.159	-0.130	0.104	0.199
VP	0.070	0.070	-0.022	0.050	0.055	0.124	0.004	0.007

**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 *Sangisorba 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.

## 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 *Sangisorba 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.

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