Habitat conditions should not be ignored when analysing plant phenology and its relation to plant functional traits in herbaceous species

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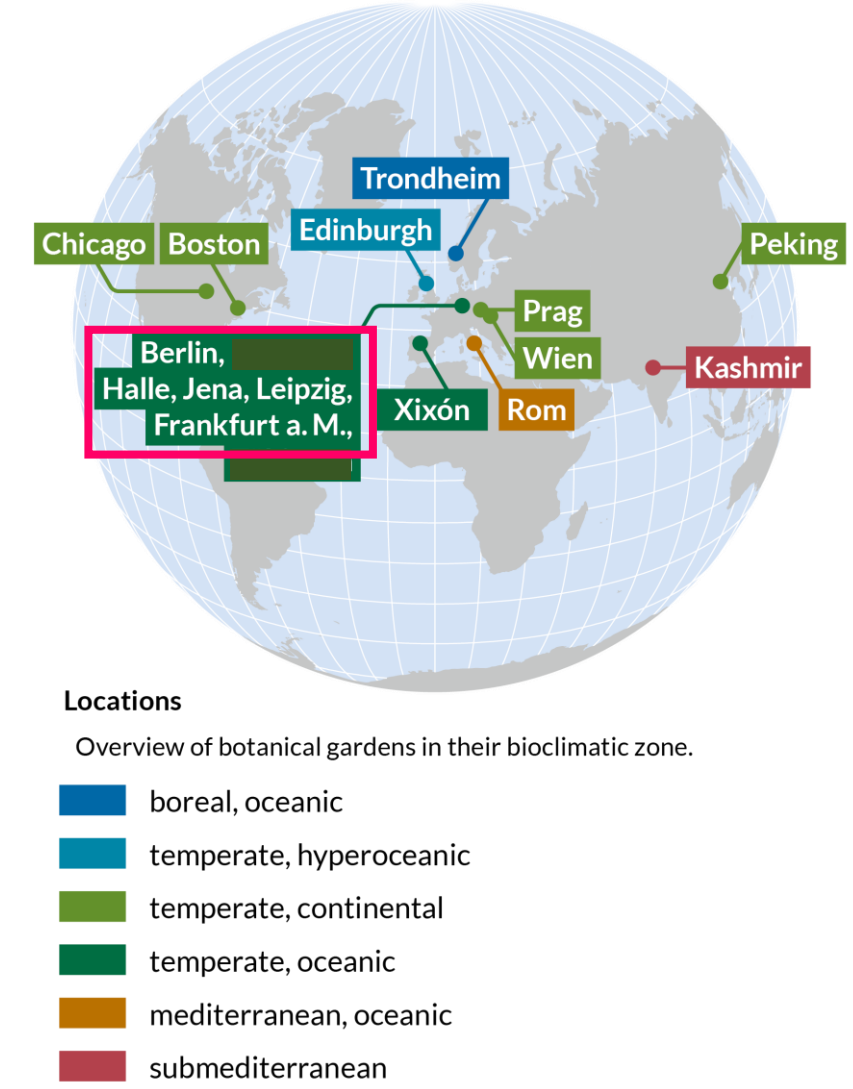
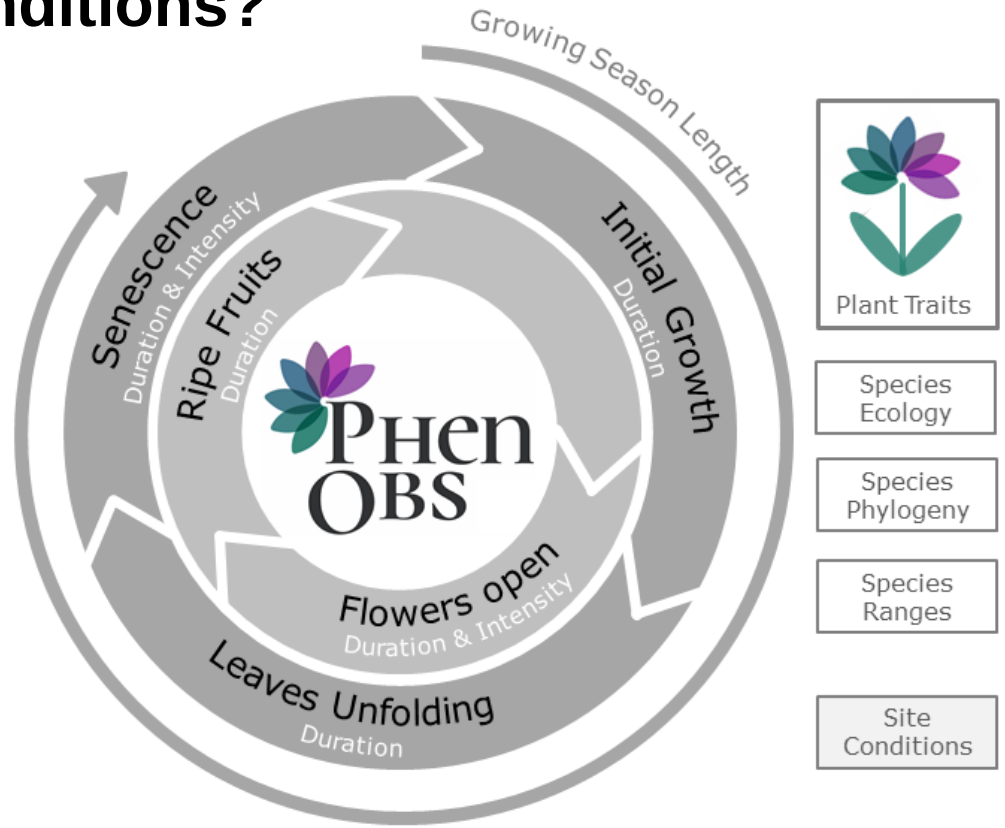
PhenObs – an observation network in Botanical Gardens to monitor herbaceous species phenology and traits



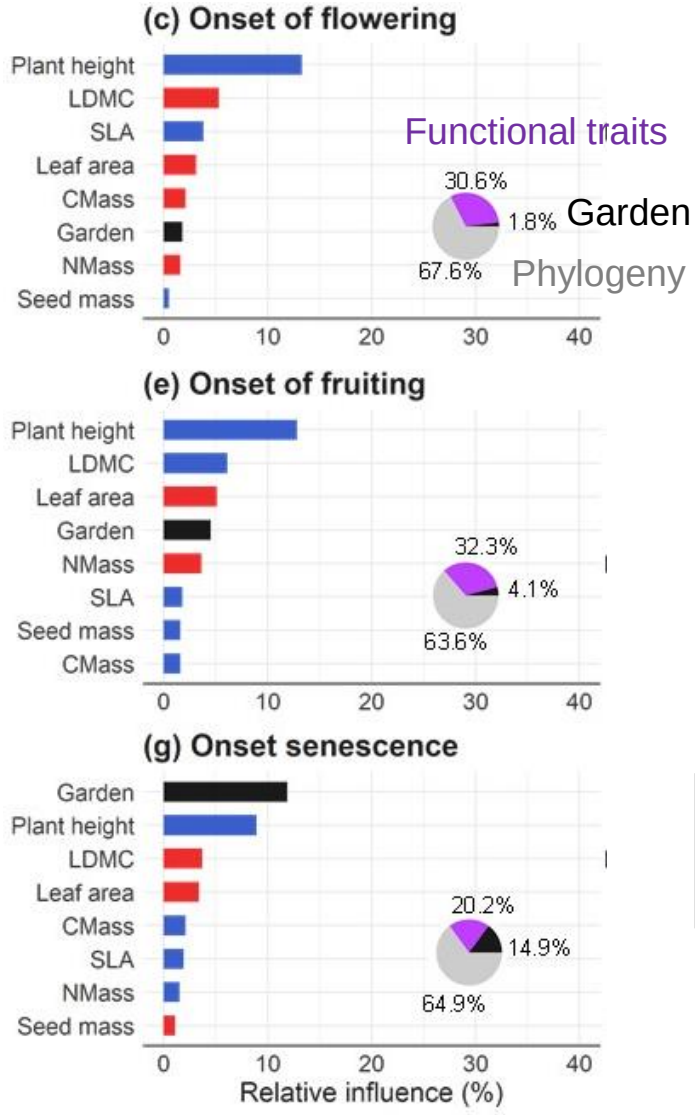
Nordt, B., Hensen, I., Bucher, S.F., Freiberg, M., Primack, R., Stevens, A.-D., Bonn, A., Wirth, C., Jakubka, D., Plos, C., Sporbert, M..& Römermann, C. (2021) The PhenObs initiative- A standardised protocol for monitoring phenological responses to climate change using herbaceous plant species in botanical gardens. ***Functional Ecology***, 35, 821-834.

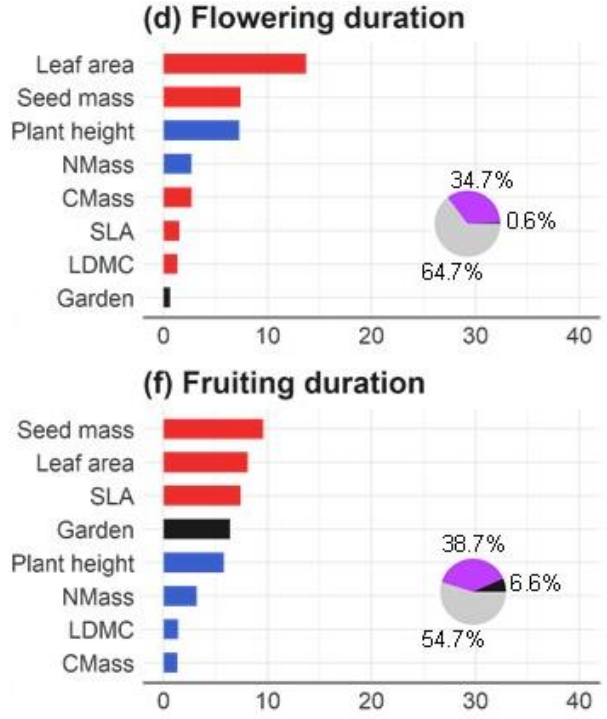
PhenObs – an observation network in Botanical Gardens to monitor herbaceous species phenology and traits

- **Which are the drivers of variations in plant phenology?**
- **Can we predict plant phenology from plant traits, species ecology, provenance, phylogeny and site conditions?**
- **What are the implications for**
  - Species performance
  - Species assembly
  - Biotic interactions
  - Ecosystem processes
  - Ecosystem functions



First results show that functional traits constrain the variation in herbaceous species phenology





Positive influence
Negative influence
Categorical (garden)

- **Taller plants** flowered, fruited and underwent leaf senescence later
- **Large-leaved species** had shorter flowering and fruiting durations

Sporbert M et al. (accepted) ***New Phytologist***

212 species, five gardens (Halle, Jena, Leipzig, Berlin, Frankfurt)

But how well do observations in Botanical gardens reflect patterns from (semi-)natural habitats?

Centaurea jacea in grasslands and in the botanical garden Jena.
Picture credit: T. Deilmann

Till Deilmann

Species and site selection

…in total 16 perennial species observed in the botanical garden (BG) and semi-natural habitats (MG and/or SDG)

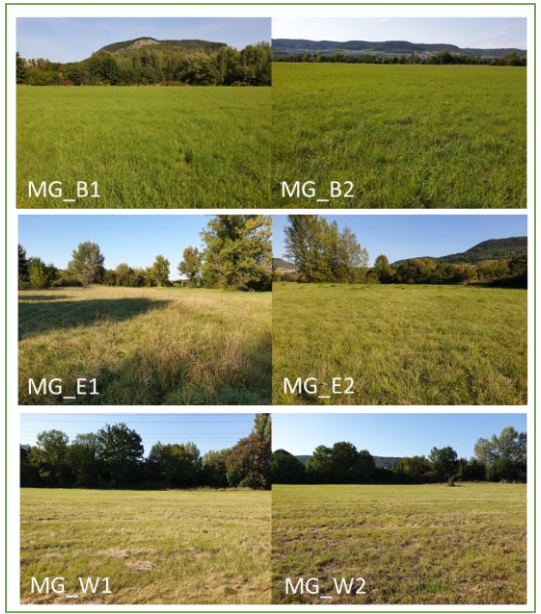
Botanical Garden Jena (BG)

mesophilic grasslands (MG) N= 6

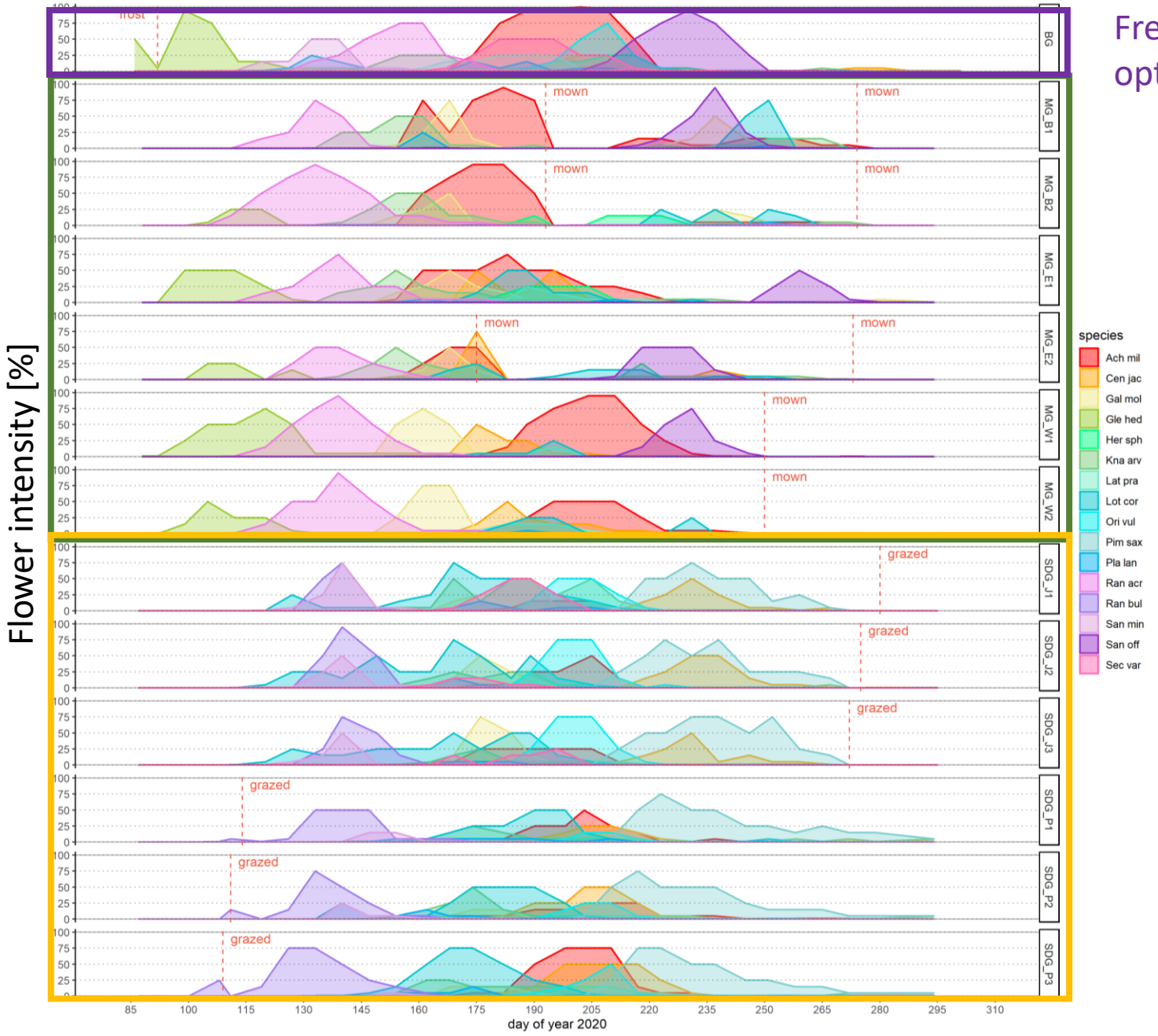
semi-dry grasslands (SDG) N= 6

Botanical Garden →

mesophilic grasslands



semi-dry grasslands



Day of the year 2020

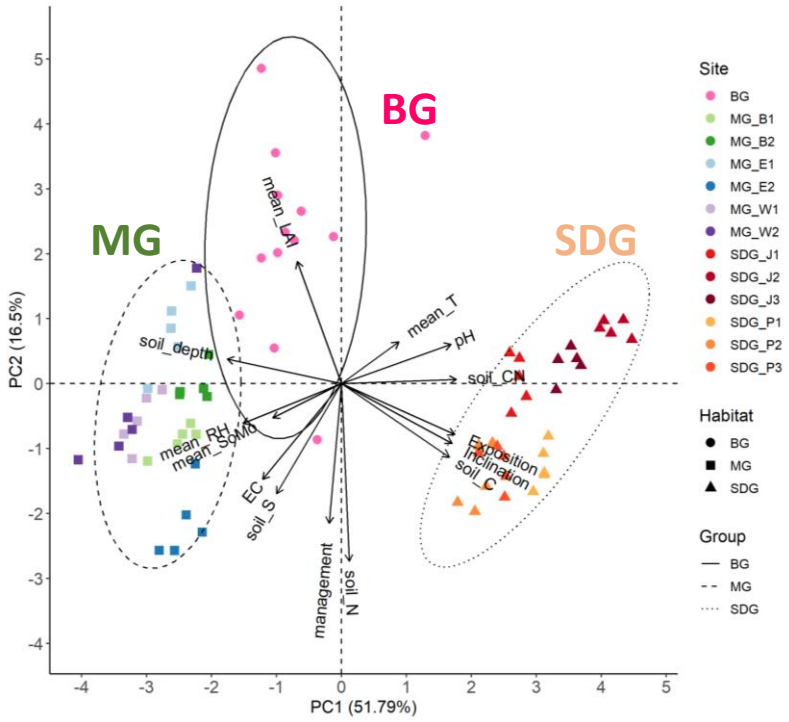
Free of competition, optimal conditions

temporal segregation

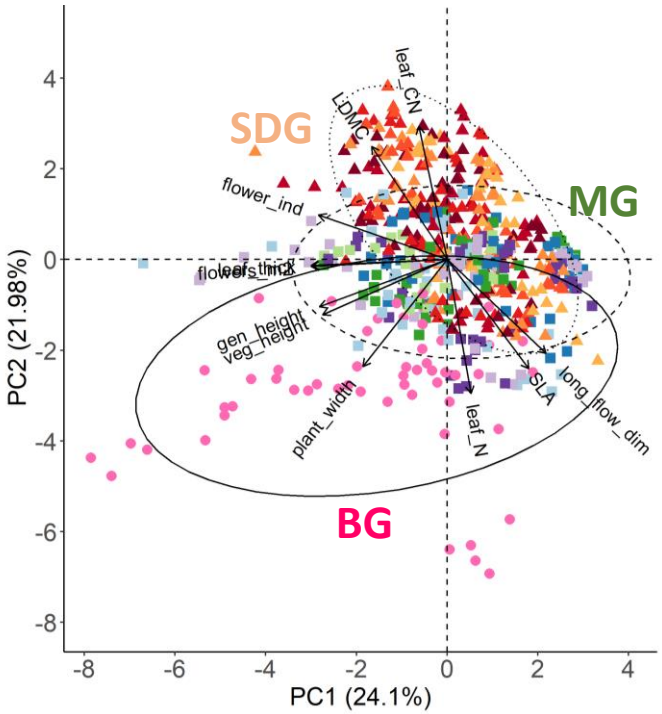
flowering synchrony

Differences in abiotic habitat conditions translate into differences in traits but not phenology

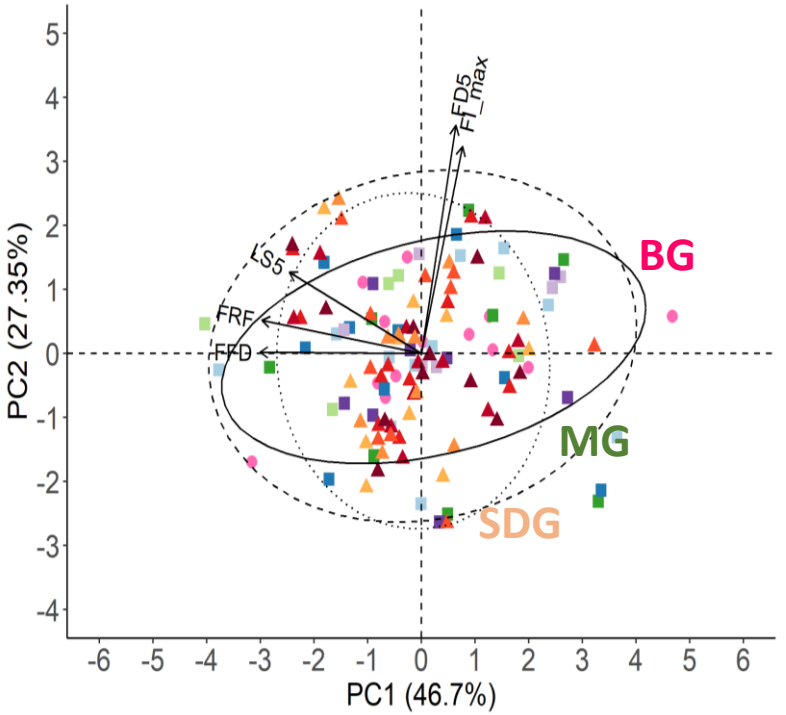
abiotic conditions



plant traits

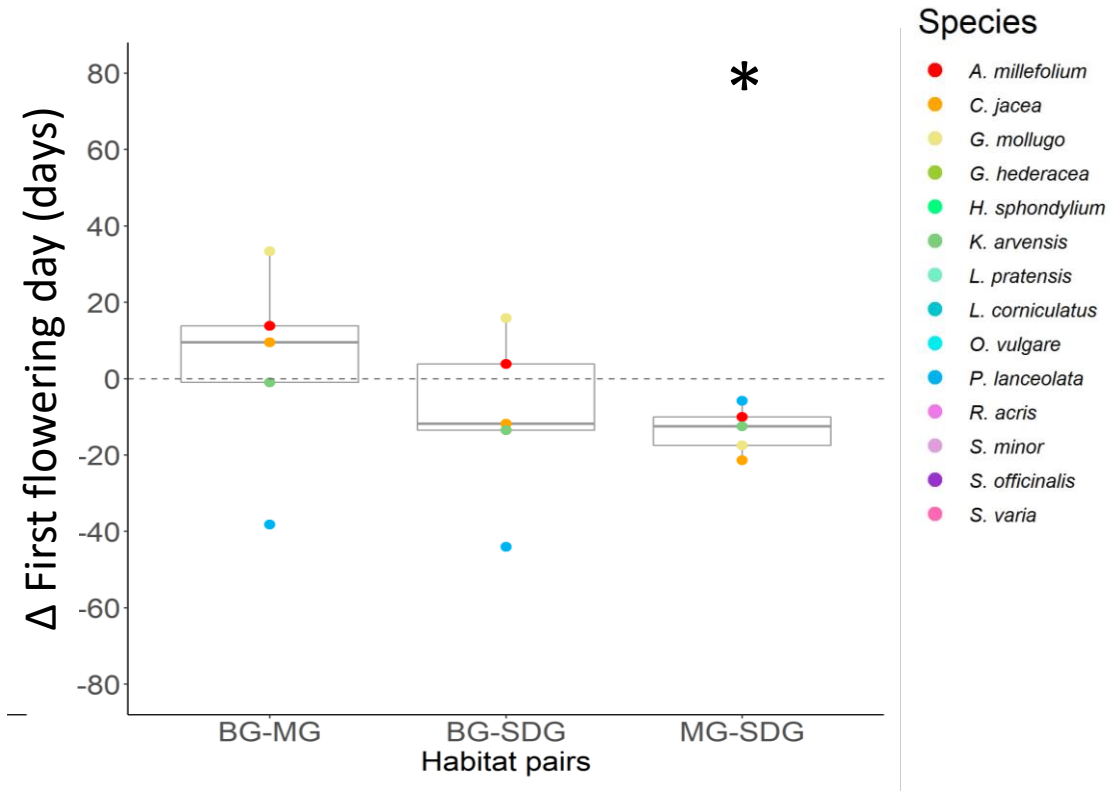


plant phenology



Differences in first flowering day between the habitats…

First Flowering Day



Species-specific patterns

On average…

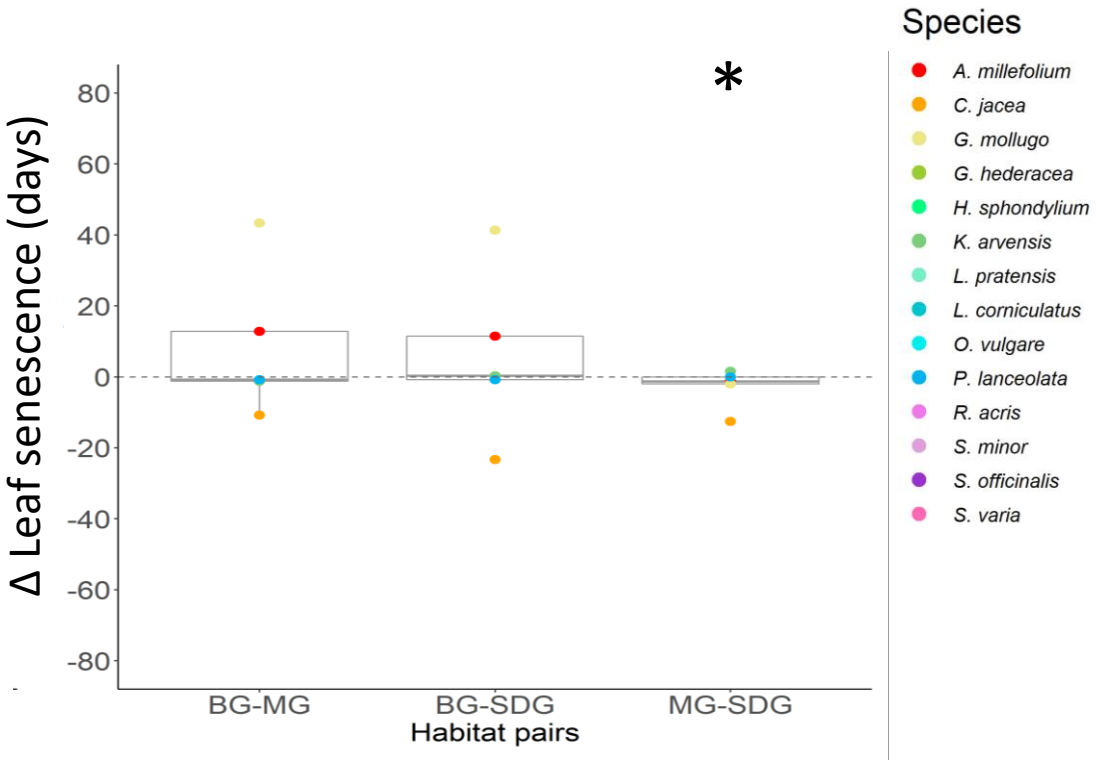
➔ no significant difference between populations grown in botanical gardens and their natural habitats

➔ an earlier FFD of ten days in mesophilous compared to semi-dry grasslands

MG- SDG: $F_{2, 57} = 0.23$, $p < 0.05$

No differences in start of senescence between the habitats…

Start of senescence



Species-specific patterns

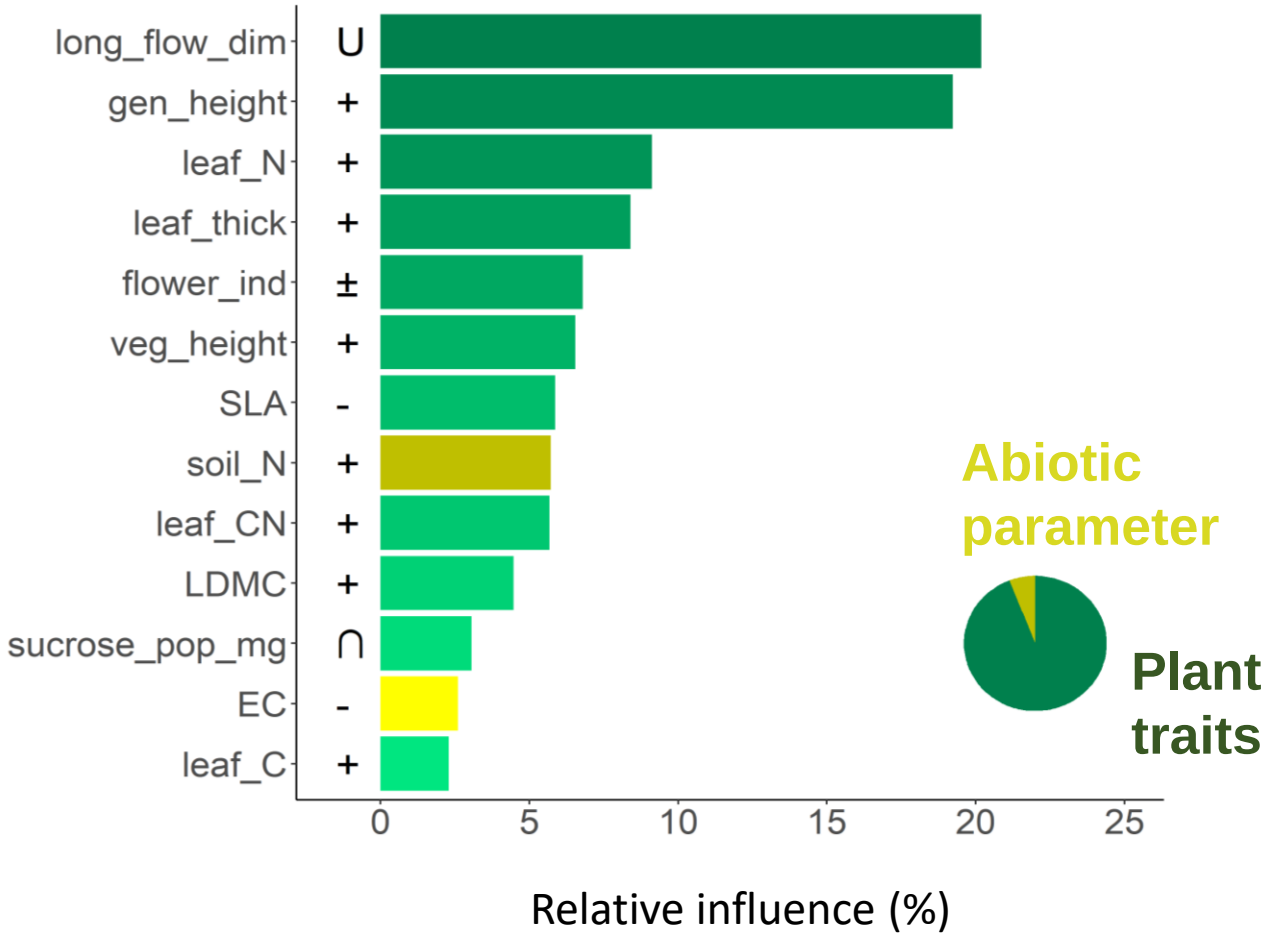
On average…

➔ no significant difference between populations grown in botanical gardens and their natural habitats

➔ a slightly earlier start of senescence in mesophilous compared to semi-dry grasslands

MG- SDG: $Chi^2 = 7.83$, $p < 0.05$

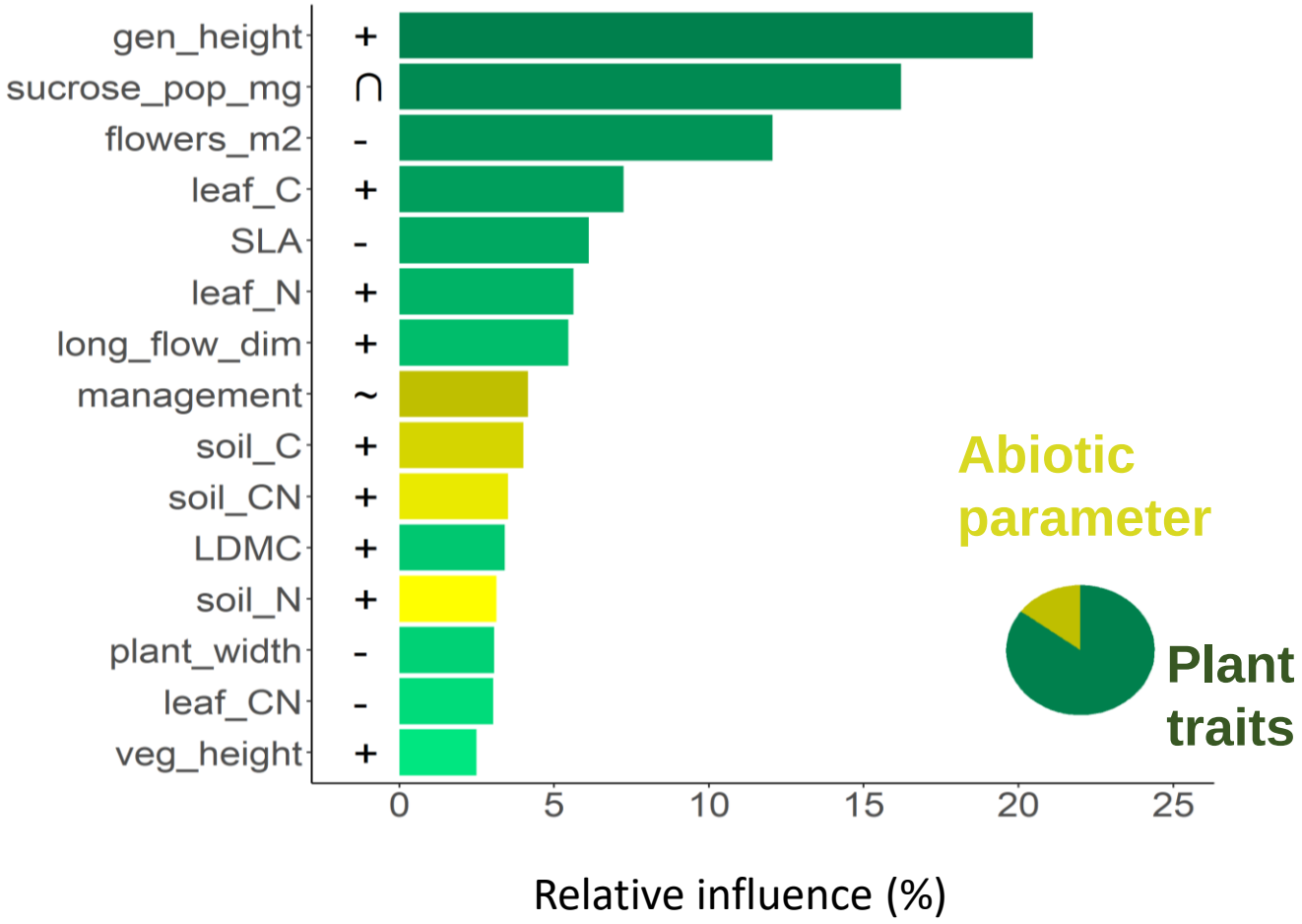
What are the drivers of phenology in the different habitats?
Here: first flowering day



- across all habitats, traits are most important to explain variations in FFD
- habitat-specific differences in soil conditions more important than climate

- As before in PhenObs dataset: taller plants flowered later!

What are the drivers of phenology in the different habitats?
Here: start of senescence



- across all habitats, traits are most important to explain variations in senescence
- habitat-specific association between traits and senescence

- As before in PhenObs dataset: taller plants senesced later!

PhenObs
Botanical Gardens as a Global Phenological Observation Network

Summary

- Phenology patterns differ between habitats with temporal segregation in mesophilous grasslands and flowering synchrony in dry grasslands.

- There is no unique patterns in the differences of first flowering day and start of senescence between the garden and the other populations

- Traits are most important predictors of FFD and start of senescence;
  edaphic conditions are more important than climate.

- Across all datasets, plant height is an important driver of herbaceous species' phenology, with taller plants flowering and senescing later than smaller plants.

Acknowledgements

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- The gardeners for supporting the project
- The PhenObs consortium

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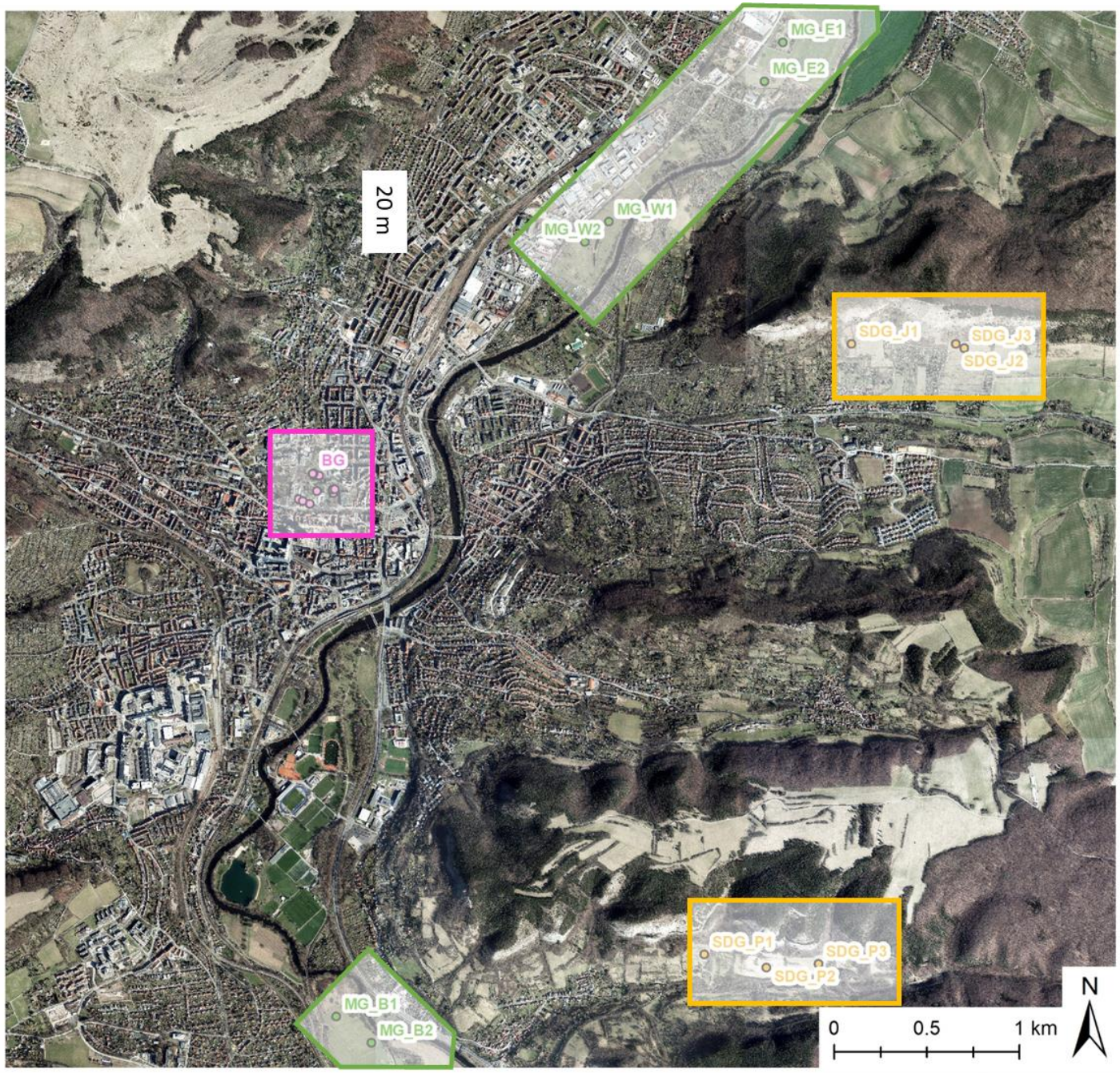
Data acquisition

- 13 sites (6 MG, 6 SDG, BG)
- Weekly phenological observation of 16 species in total
  → 11 on MG and SDG each
  → 6 match species
- Abiotic parameters
  → for each site
- Plant functional traits
  → 5 individuals/population

BG = Botanical garden, MG = mesophilous grassland, SDG = semi-dry grassland



https://www.geoportal-th.de/de-de/ (Access: May 2020)
https://www.geoportal-th.de/de-de/ (Access: May 2020)

Species selection

- **Investigated species:**
  - 11 characteristic and/or typical species for each habitat (16 in total)
  - same species in Botanical Garden*
  - 6 match species
  - broad family distribution

Mesophilic grassland		Semi-dry grassland	
species	**family**	**species**	**family**
Knautia arvensis	Caprifoliaceae	*Knautia arvensis*	Caprifoliaceae
Achillea millefolium agg.	Asteraceae	*Achillea millefolium* agg.	Asteraceae
Plantago lanceolata	Plantaginaceae	*Plantago lanceolata*	Plantaginaceae
Galium mollugo agg.	Rubiaceae	*Galium mollugo* agg.	Rubiaceae
Centaurea jacea agg.	Asteraceae	*Centaurea jacea* agg.	Asteraceae
Lotus corniculatus	Fabaceae	*Lotus corniculatus*	Fabaceae
Sanguisorba officinalis	Rosaceae	*Sanguisorba minor*	Rosaceae
Ranunculus acris	Ranunculaceae	*Ranunculus bulbosus*	Ranunculaceae
Lathyrus pratensis	Fabaceae	*Securigera varia*	Fabaceae
Glechoma hederacea	Lamiaceae	*Origanum vulgare*	Lamiaceae
Heracleum sphondylium	Apiaceae	*Pimpinella saxifraga*	Apiaceae

* besides *P. saxifraga, L. corniculatus, R. bulbosus*

Measured parameters

- Abiotic parameters
  - exposition, inclination, management
  - weather data
  - soil characteristics (moisture, nutrients, depth, ...)
  - vegetation composition (Ellenberg values; competition)
  - shading (LAI)

+

Functional traits:

Plant trait	Ecological function	References
Specific leaf area Leaf nitrogen content	Productivity, competitive ability	Pérez-Harguindeguy et al. (2016), Garnier (1992)
Leaf dry matter content Leaf carbon content Leaf thickness	Resistance, leaf lifespan	Pérez-Harguindeguy et al. (2016), Blumenthal et al. (2020)
Plant height, plant growth	Competitive ability, fecundity	Pérez-Harguindeguy et al. (2016), Gaudet and Keddy (1988)
Nectar sucrose content	Pollinator reward	Fornoff et al. (2017)
Flower size, flower density	Reproductive success, pollination	Sih and Baltus (1987), Comba (1999), Hegland and Totland (2005), Fornoff et al. (2017)
Pollen size	Pollination, viability	Kearns and Inouye (1993), Kelly et al. (2002)
Pollen fluorescence	Pollinator attraction, UV-protection	Mori et al. (2018)

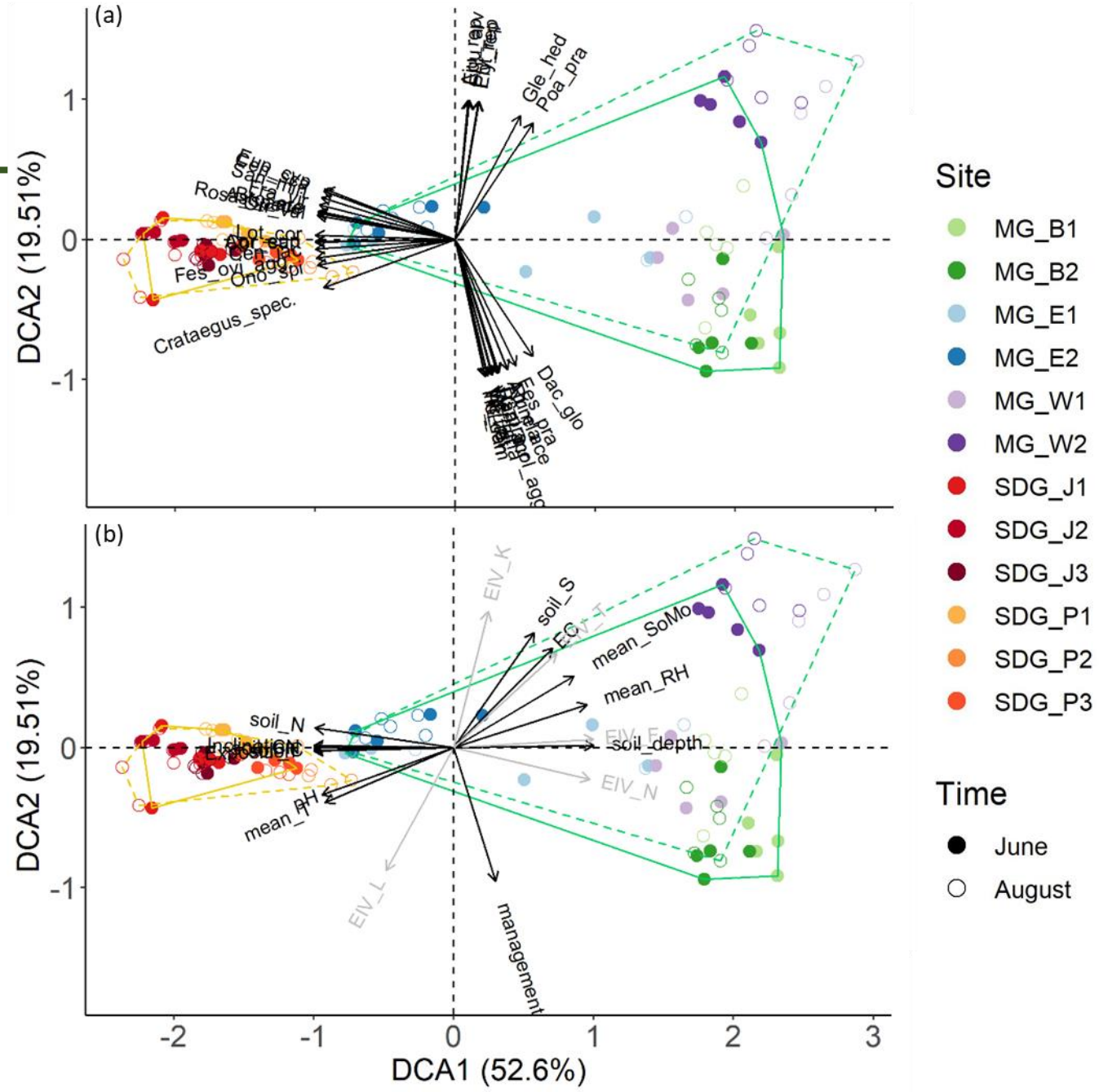
Abiotic factors

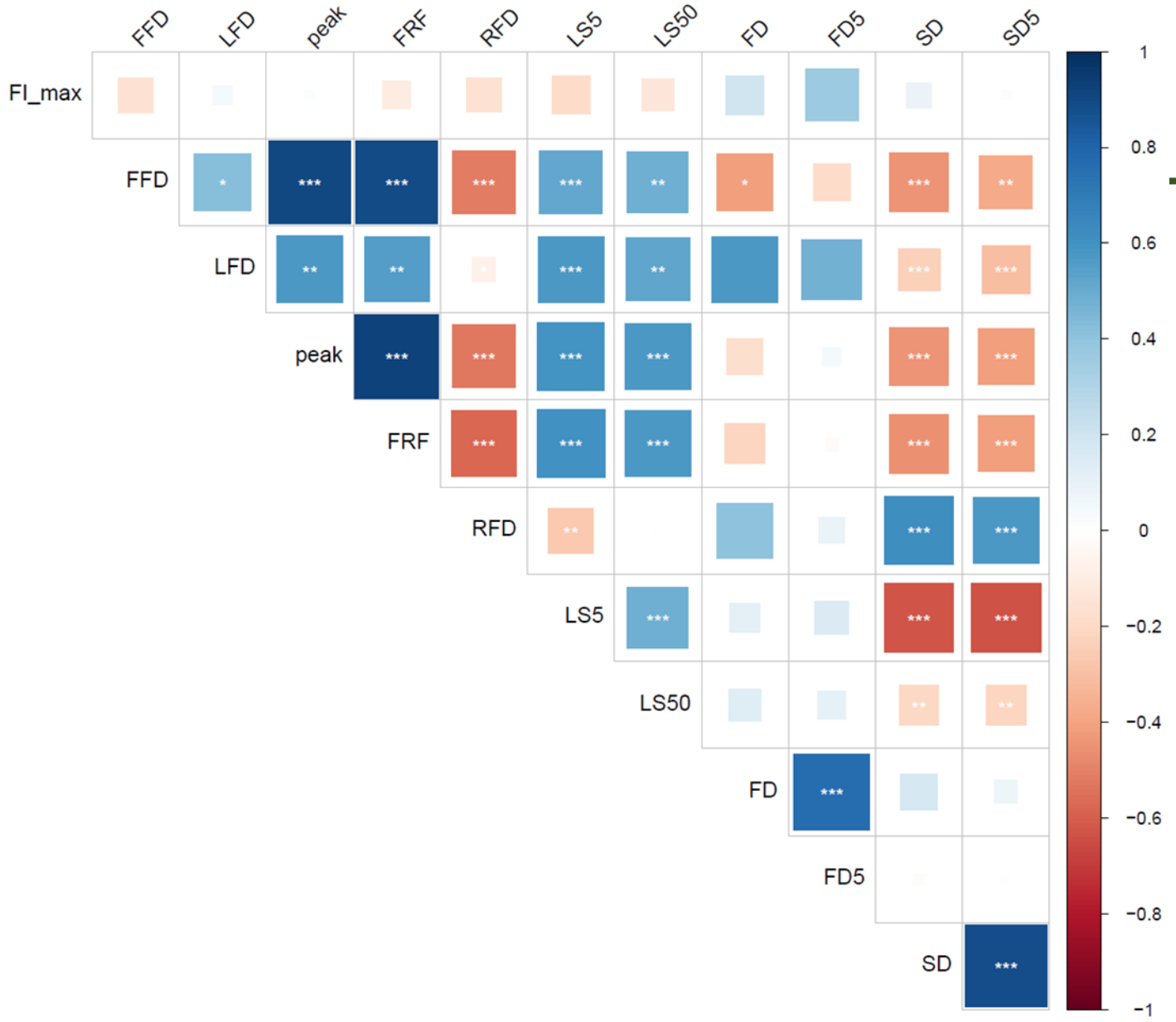
Parameter	BG	MG	SDG
Exposition [°]	0 **a**	0 **a**	178.93 ± 1.77 **b**
Inclination [°]	0 **a**	0 **a**	15.44 ± 0.48 **b**
Soil depth [cm]	84.8 ± 8.63 **a**	100 **b**	8.96 ± 0.42 **c**
pH	7.7 ± 0.04 **a**	7.48 ± 0.01 **b**	7.87 ± 0.01 **c**
EC [µS cm^{-1}]	206.62 ± 11.73 **a**	339.33 ± 14.66 **b**	224.07 ± 3.34 **a**
soil C:N ratio	18.33 ± 1.18 **a**	12.93 ± 0.42 **b**	29.51 ± 0.78 **c**
soil N content [%]	0.27 ± 0.02 **a**	0.34 ± 0.01 **b**	0.35 ± 0.01 **b**
Soil moisture mean [% vol]	17.86 ± 0.82 **a**	21.84 ± 0.52 **b**	17.02 ± 0.55 **c**
Soil moisture min [% vol]	2	7.16	6.14
Soil moisture max [% vol]	34.72	41.42	40.64
LAI mean	1.92 ± 0.16 **a**	1.91 ± 0.09 **a**	1.3 ± 0.06 **b**
LAI min	0	0.01	0
LAI max	6.73	5.19	4.09
Daily temperature mean [°C]	15.84 ± 0.32 a	15.33 ± 0.13 a	15.49 ± 0.13 a
Daily temperature min [°C]	5.72	4.94	4.62
Daily temperature max [°C]	26.48	25.94	27.66
Daily rel. humidity mean [%]	70.42 ± 0.7 **a**	73.13 ± 0.26 **b**	68.83 ± 0.38 **a**
Daily rel. humidity min [%]	50.95	49.23	29.45
Daily rel. humidity max [%]	93.84	95.51	99.98
Weighted Ellenberg N-value	- -	5.51 ± 0.2 **a**	2.89 ± 0.05 **b**
Weighted Ellenberg L-value	-	7.02 ± 0.09 **a**	7.5 ± 0.03 **b**
Weighted Ellenberg T-value	-	5.54 ± 0.04 **a**	5.21 ± 0.01 **b**
Weighted Ellenberg F-value	-	4.61 ± 0.12 **a**	3.34 ± 0.02 **b**
Weighted Ellenberg R-value	-	7.32 ± 0.07 a	7.12 ± 0.12 a
Weighted Ellenberg K-value	-	3.29 ± 0.12 **a**	2.91 ± 0.05 **b**

Vegetation composition

(a) species vectors

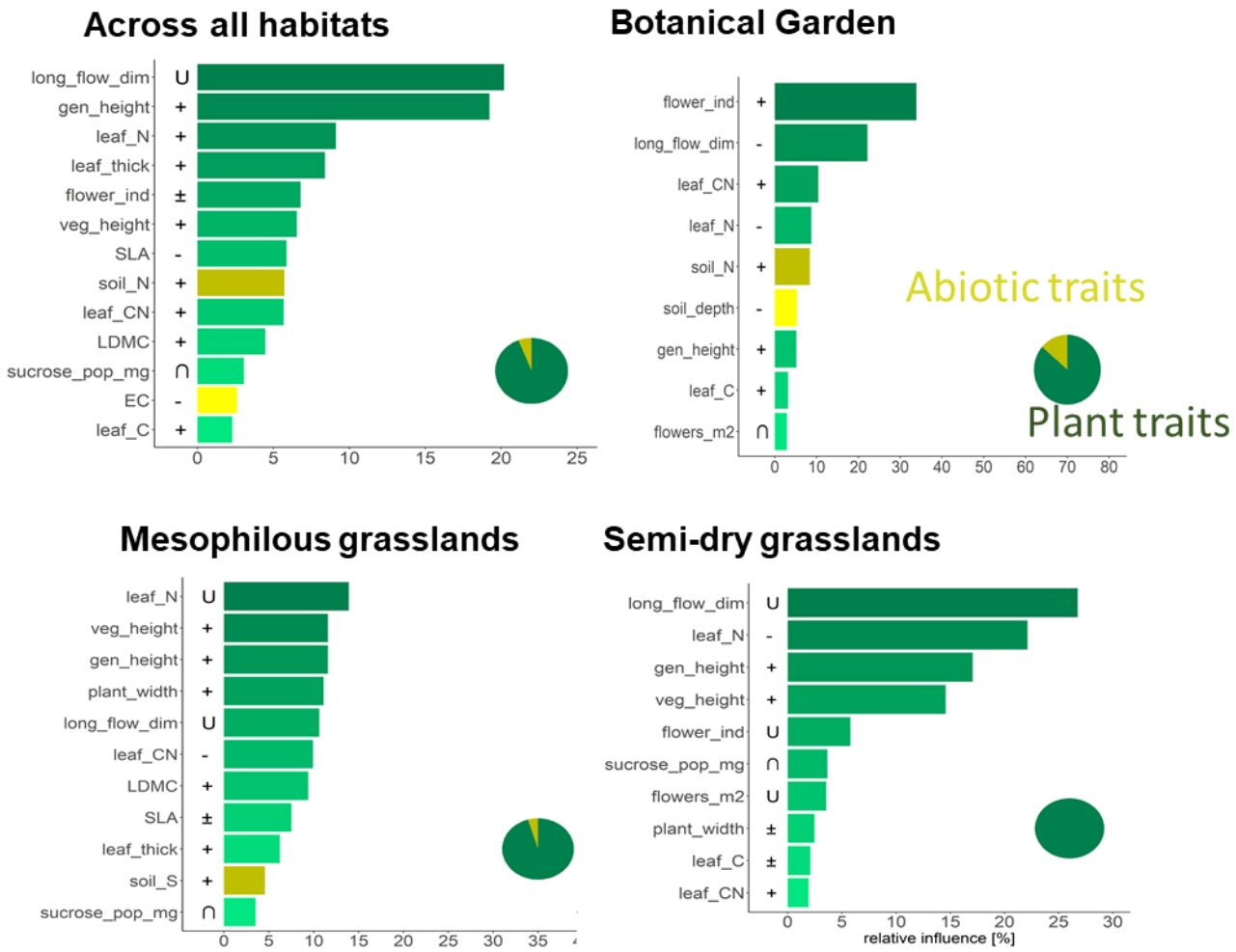
(b) abiotic vectors





Correlations of phenological traits

What are the drivers of phenology in the different habitats?
Here: first flowering day



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- habitat-specific association between traits and FFD

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