Supplementary Information

for the manuscript

Number of growth days and not length of the growth period determines radial stem growth of temperate trees

Sophia Etzold[1*], Frank Sterck[2], Arun K. Bose[1,3], Sabine Braun[4], Nina Buchmann[5], Werner Eugster[5], Arthur Gessler[1,6], Ansgar Kahmen[7], Richard L. Peters[1,8,9], Yann Vitasse[1], Lorenz Walthert[1], Kasia Ziemińska[1,10], Roman Zweifel[1]

This Supplementary Information includes four tables and 9 figures.

Tables

TABLE S1. Tree species and their occurrence at the 47 sites including sometimes several plots with different exposition, vegetation and soil. Forest types indicate either coniferous (including pure), deciduous (including pure) or mixed forests. MY: measurement years x tree individuals measured, ELE: range of elevation, MAT: range mean annual temperature of the sites from 2014-2018, MAP: range of mean annual sum of precipitation at the sites from 2014-2018, DBH: range of tree stem diameter at breast height, TH: range of tree height.

Species	Forest types	Sites [n]	Trees [n]	MY [yrs]	ELE [m asl]	MAT [°C]	MAP [mm]	DBH [cm]	TH [m]
P. abies	Coniferous; mixed	18	55	309	480-1650	4.5-11.9	664-1487	20-103	17-40
P. sylvestris	Coniferous; mixed	10	21	101	420-1520	5.0-11.3	600-1020	15-57	9-25
A. alba	Coniferous, mixed	5	10	63	480-1510	6.1-10.0	943-1577	34-88	27-40
F. sylvatica	Deciduous, mixed	21	45	238	460-1030	8.7-11.9	820-1577	14-90	11-39
F. excelsior	Mixed	4	7	49	690-700	9.6-10.1	640-1577	14-68	8-39
Q. petraea	Deciduous, mixed	4	10	63	460-630	10.1-11.2	826-973	18-68	13-25
Q. pubescens	Deciduous, mixed	6	12	61	630-870	10.1-12.1	598-920	14-31	7-14

TABLE S2. Species-specific characteristics of growth (median with 50% range in brackets). GRO_{start} = start of the growth period, GRO_{end} = end of the growth period. GRO_{length} = growth period length, N days with growth = number of days with growth within growth period, % days with growth=Percentage coverage of days with growth within growth period. Letters indicate significant different groups, tested by Kruskal-Wallis and post-hoc Dunn test. For number of sites, trees and years, see **Table S1**.

	Annual stem growth [mm yr^{-1}]	**GRO_{start} [DOY]**	**GRO_{end} [DOY]**	**GRO_{length} [days]**	**Vegetation period [days]**	**N days with growth [days]**	**% days with growth [%]**	**Median daily growth rate [µm day^{-1}]**
P. abies	1.51^{a} (1.15-2.01)	133^{a} (119-148)	235^{a} (222-243)	98 (84-113)	246 (227-250)	43^{ab} (32-65)	51^{a} (39-61)	22.8^{a} (21.6-26.1)
P. sylvestris	0.80^{b} (0.56-1.01)	134^{a} (128-143)	222^{ab} (206-239)	92 (72-109)	226 (210-250)	29^{a} (19-54)	39^{a} (29-47)	17.6^{ac} (15.2-18.8)
A. alba	1.82^{a} (1.59-2.94)	117^{ab} (116-122)	242^{a} (240-246)	117 (112-128)	250 (246-250)	78^{b} (73-81)	64^{ab} (63-68)	16.4^{abc} (11.6-18.3)
F. sylvatica	1.12^{ab} (0.89-1.53)	121^{a} (118-133)	219^{ab} (204-226)	91 (84-97)	250 (250-267)	67^{b} (57-73)	80^{b} (72-91)	9.1^{b} (5.6-10.2)
F. excelsior	1.44^{ab} (1.19-2.12)	109^{ab} (108-110)	217^{ab} (203-226)	109 (93-118)	250 (250-250)	56^{ab} (44-66)	52^{ab} (48-56)	15.6^{abc} (15.3-18.6)
Q. petraea	1.07^{ab} (0.81-1.40)	104^{b} (99-106)	217^{ab} (214-220)	113 (112-116)	254 (245-261)	58^{ab} (44-71)	54^{ab} (46-58)	11.2^{bc} (9.5-12.9)
Q. pubescens	0.66^{b} (0.51-0.72)	104^{b} (99-107)	203^{b} (200-210)	101 (98-103)	259 (258-270)	32^{a} (30-34)	29^{a} (23-35)	11.6^{bc} (8.7-13.6)

TABLE S3. Results of the linear mixed-effects models for the seven tree species with annual growth as response variable, and tree nested in site nested in species as random effect. The response curves of this model are displayed in **Figure S8**. With N $days_{growth}$ = number of days with growth, GRO_{start}=start of the growth period, GRO_{end}= end of the growth period, GRO_{length}=length of the growth period, "x^2"=squared term to account for non-linearity, "-" indicates that this term was not significant in the final model.

Fixed Effects	***Picea abies***	***Pinus sylvestris***	***Abies alba***	***Fagus sylvatica***	***Fraxinus excelsior***	***Quercus petraea***	***Quercus pubescens***
N $days_{growth}$	0.46±0.03	0.53±0.03	0.30±0.05	0.47±0.03	0.41±0.04	0.42±0.05	0.42±0.03
Daily growth rate	0.23±0.02	0.26±0.03	0.32±0.04	0.36±0.03	0.24±0.04	0.26±0.05	0.12±0.03
GRO_{start}	-	-	-	-	-	-	-
GRO_{start}^2	-0.08±0.02	-	-	-	-	-	-
GRO_{length}	0.30±0.06	-	-	-	-	-	-
GRO_{length}^2	-0.33±0.06	-	-	-0.12±0.02	-	-0.61±0.11	-
GRO_{end}	-	-	-	-	-	-	-
GRO_{end}^2	-	-	-	-	-	0.53±0.11	-
Random Effects							
site	0.04	0.03	0.15	0.000	0.000	0.18	0.15
tree:site	0.01	0.11	0.32	0.17	0.17	0.16	0.21
Residual	0.04	0.21	0.15	0.23	0.18	0.17	0.18
N observations	224	77	46	170	37	40	56
N trees	49	20	10	42	7	10	12
N sites	17	10	5	20	4	4	6
Marginal R^2	0.73	0.88	0.65	0.87	0.86	0.72	0.69
Conditional R^2	0.87	0.90	0.94	0.92	0.91	0.90	0.89

TABLE S4. Standardized coefficients of fixed effects ± standard error derived from generalized mixed effects models (GLMM) with growth/no growth as binary response variable, and year, tree and site as nested random effects. Included is the time period from April to September (DOY 90 -270). Significance is indicated with ***p<0.001, **p<0.01, *p<0.05. '-.' indicates that this variable was not included in the final model. RelH had to be removed in all models due to collinearity with VPD, whereby VPD was always higher correlated to the response variable.

		Picea abies	***Pinus sylvestris***	***Abies alba***	***Fagus sylvatica***	***Fraxinus excelsior***	***Quercus petraea***	***Quercus pubescens***
VPD		-1.47 ±0.04***	-1.40 ±0.05***	-1.14 ±0.06***	-0.80 ±0.04***	-0.13 ±0.06*	-0.53 ±0.07***	-0.67 ±0.08***
SWP		0.16 ±0.02***	0.85 ±0.04***	0.07 ±0.03*	1.03 ±0.03***	1.07 ±0.09***	0.92 ±0.07***	1.08 ±0.07***
Temp		0.92 ±0.03***	0.62 ±0.05***	0.52 ±0.05***	0.28 ±0.03***	-0.60 ±0.05***	-0.16 ±0.05***	-0.01 ±0.07
RAD		-0.12 ±0.02***	-	-0.10 ±0.05*	-0.08 ±0.03***	-	-0.03 ±0.05	-0.09 ±0.04*
Precip		0.12 ±0.02***	0.19 ±0.02***	0.16 ±0.03***	0.21 ±0.02***	0.21 ±0.03***	0.29 ±0.03***	0.26 ±0.03***
Day length		1.48 ±0.02***	1.31 ±0.03***	1.15 ±0.03***	1.80 ±0.03***	1.18 ±0.04***	1.10 ±0.05***	1.11 ±0.06***
VPD:Day length		0.32 ±0.03***	-	0.30 ±0.06***	0.51 ±0.04***	-	-0.58 ±0.07***	-0.32 ±0.08***
Temp:Day length		0.11 ±0.03***	-	-0.20 ±0.05***	-0.28 ±0.03***	-	0.53 ±0.06***	0.20 ±0.07**
SWP:Day length		0.06 ±0.02**	0.18 ±0.03***	-	0.07 ±0.03*	-	-0.68 ±0.07***	-0.89 ±0.07***
Precip:Day length		0.12 ±0.02***	-.	-	0.11 ±0.02***	-	-0.15 ±0.04***	-
RAD:Day length		-	-	-0.13 ±0.04**	-0.08 ±0.03**	-	-0.17 ±0.05***	-0.14 ±0.04**
VPD:SWP		-	-0.20 ±0.03***	-	0.16 ±0.02***	-	-	-
R^2	marginal	0.40	0.40	0.28	0.50	0.45	0.53	0.60
	conditional	0.56	0.62	0.52	0.71	0.53	0.65	0.65
N	Observations	44069	18042	9633	34608	7572	8917	10961
	Years	257	101	57	207	45	54	61
	Trees	49	21	10	42	7	10	12
	Sites	15	10	5	19	4	4	6
N	Days with no growth	32311	14123	5326	19888	5212	5619	8893
	Days with growth	11758	3919	4307	14720	2362	3298	2068

Figures

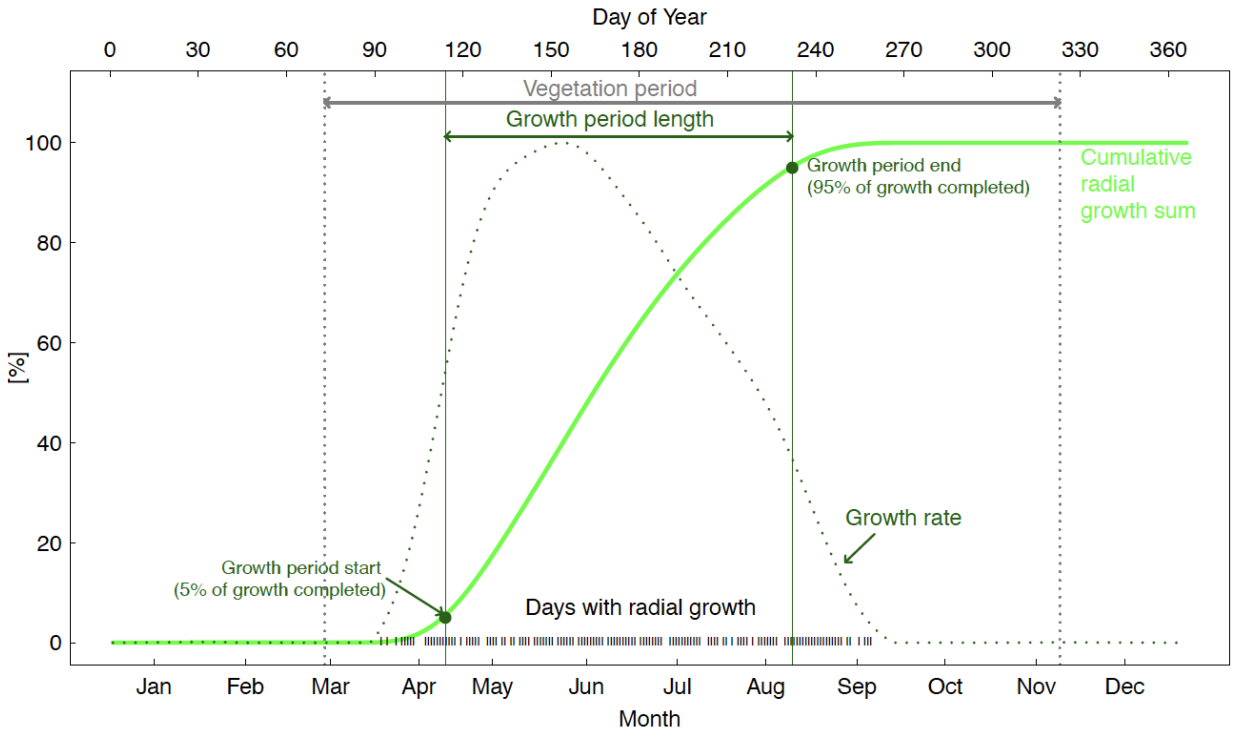

FIGURE S1 Theoretical framework of the components of stem growth, based on example data of *Abies alba*. Stem growth is governed by (i) phenology (timing), i.e., growth period start, end and length, and (ii) activity, i.e., growth rate and number of days with growth. The growth period is defined as 5-95% of the cumulative growth curve, the vegetation period is based on temperature thresholds (see Material and Methods).

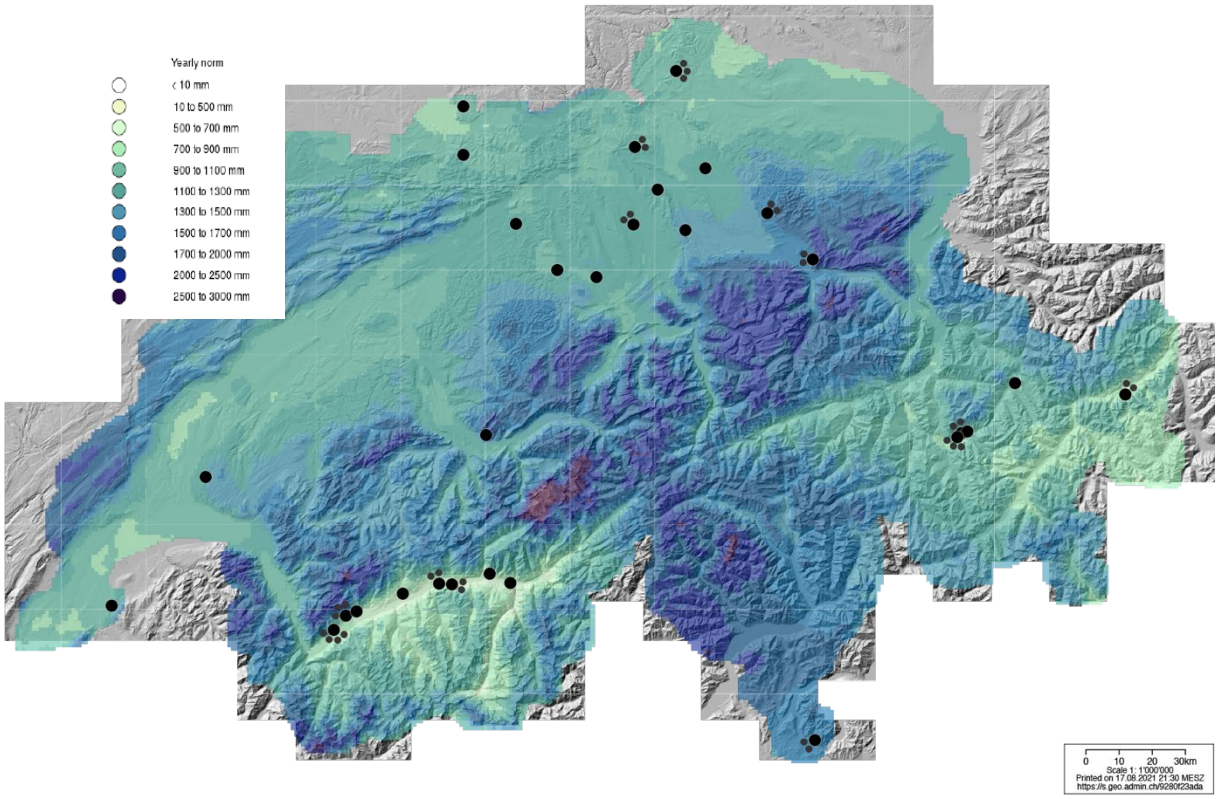

FIGURE S2. Precipitation map (yearly norm 1981-2010) of Switzerland with the 47 TreeNet study sites included in this study (latitude ranging from 45.86 to 47.68, longitude ranging from 6.29 to 10.29). Sites include sometimes several plots (smaller grey dots) with different exposition, vegetation and soil conditions. The map was created on www.map.geo.admin.ch.

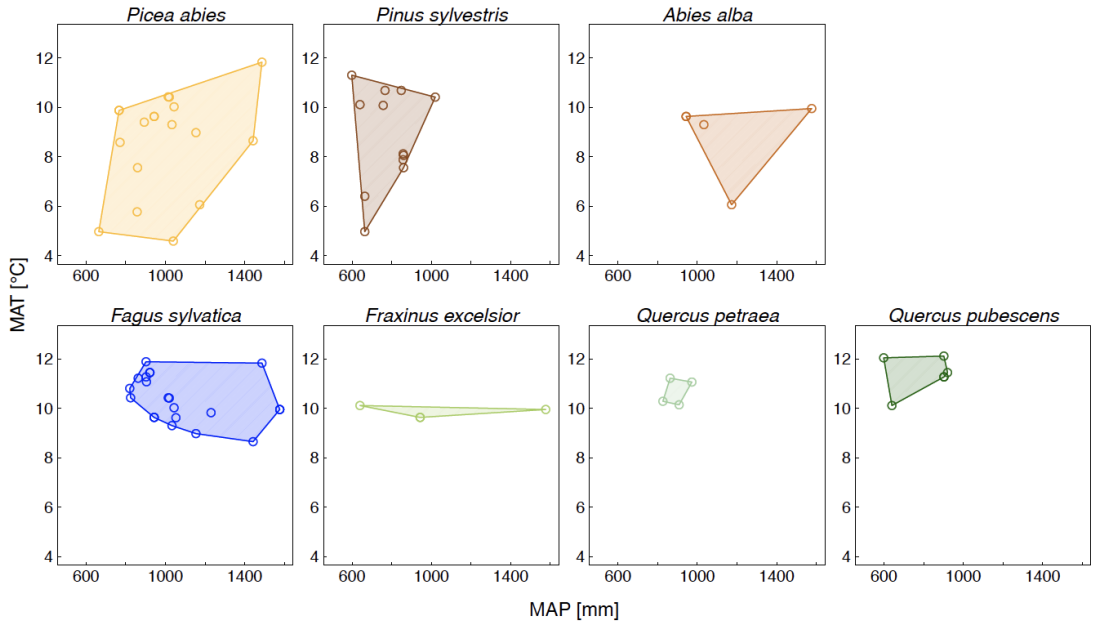

FIGURE S3 Climatic envelops of the seven species at the TreeNet sites. Mean climatic conditions from 2014-2018 at the sites with MAP = mean annual precipitation [mm], and MAT = mean annual temperature [°C]. Colours indicate different species; each dot represents a site.

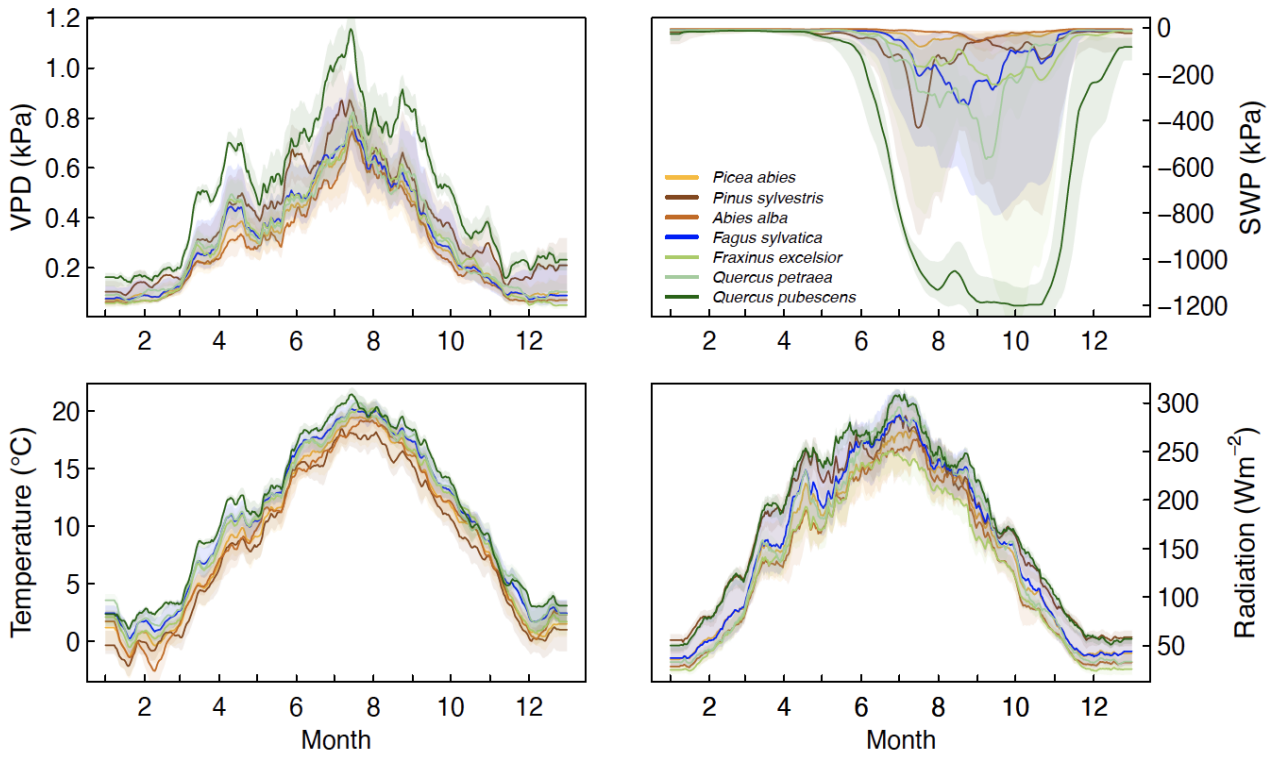

FIGURE S4. The seasonal timing of a) vapor pressure deficit (VPD), b) soil water potential (SWP), c) air temperature, and d) radiation at the TreeNet sites, separated per species. Lines indicate the median conditions at all sites per species; shaded areas indicate the interquartile range (between the 25% and 75% quantiles).

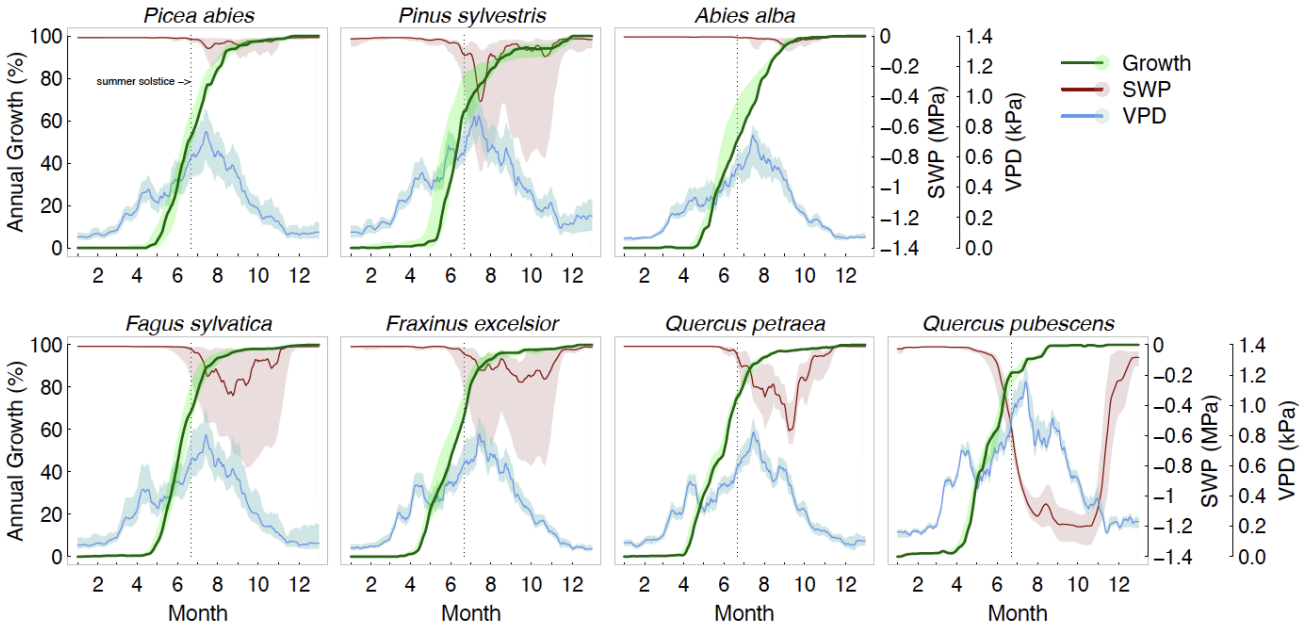

FIGURE S5. The seasonal timing of growth. Stem growth of seven tree species: median (green) with the 25-75% quantile range (light green area). The median soil water potential (SWP) is indicated in red (+/- 25% quantile), and median vapor pressure deficit (VPD) in turquoise (+/- 25% quantile).

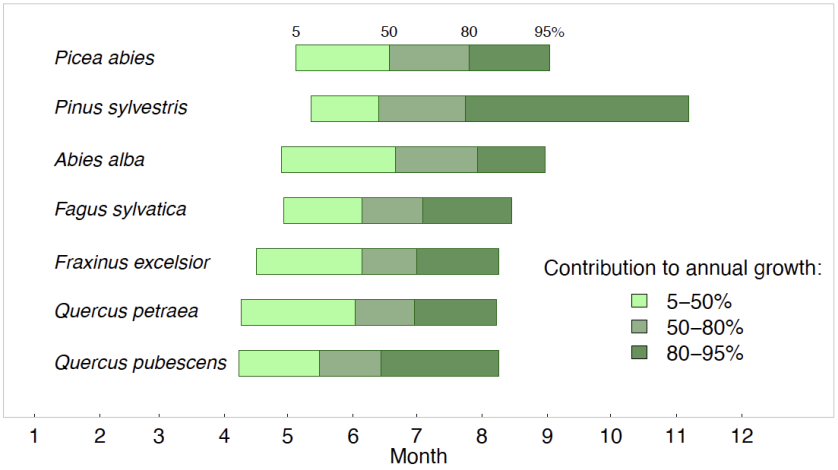

FIGURE S6. Median percentage contribution to annual growth during the growth period for seven tree species.

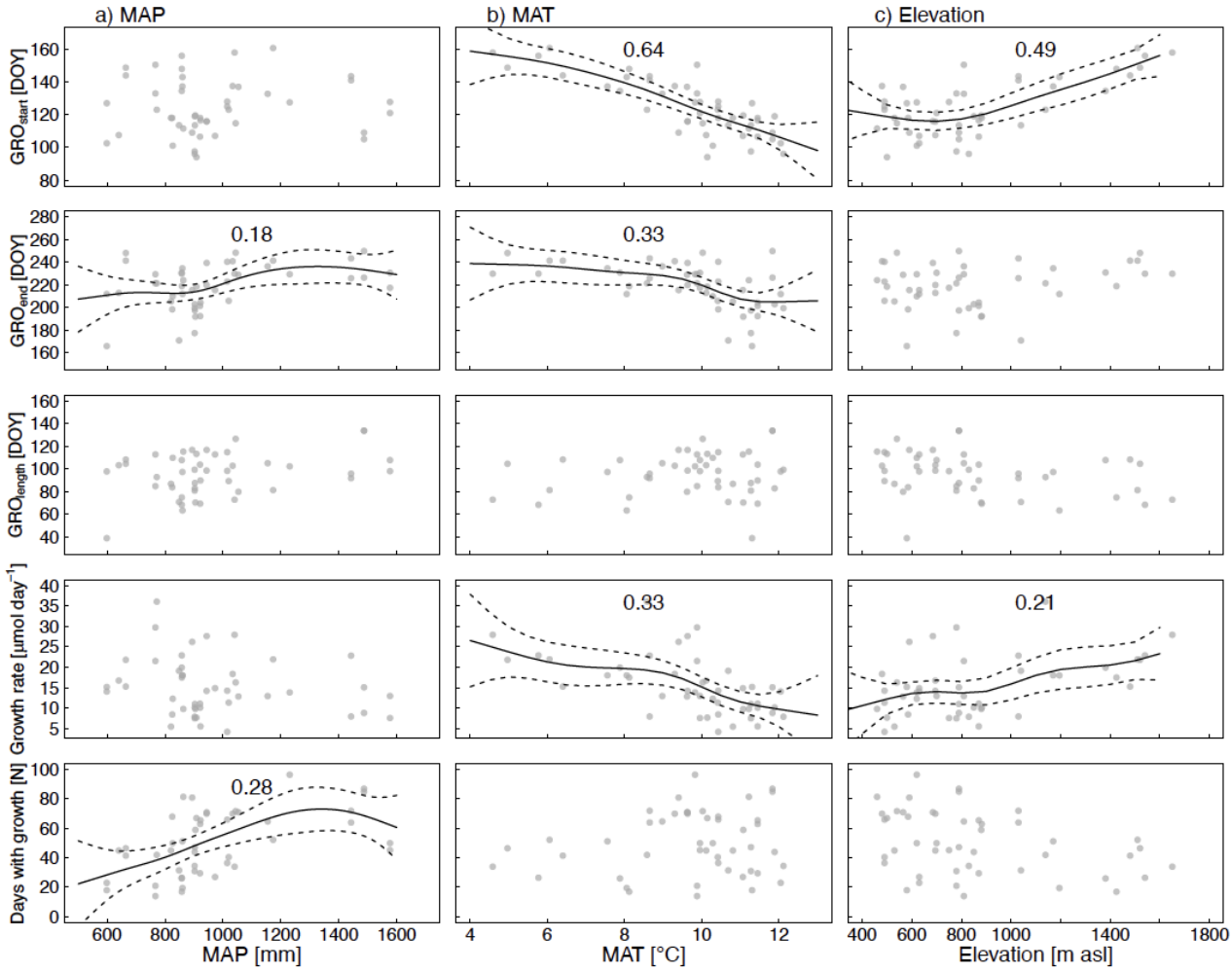

FIGURE S7. Generalized additive models of growth characteristics against site conditions: a) mean annual precipitation (MAP), b) mean annual temperature (MAT), and c) elevation. Displayed are site averages, independent of species. Black lines show significant fits of the GAM, the dotted lines indicate the 95%-confidence intervals. The number gives the adj. R^2 of the model.

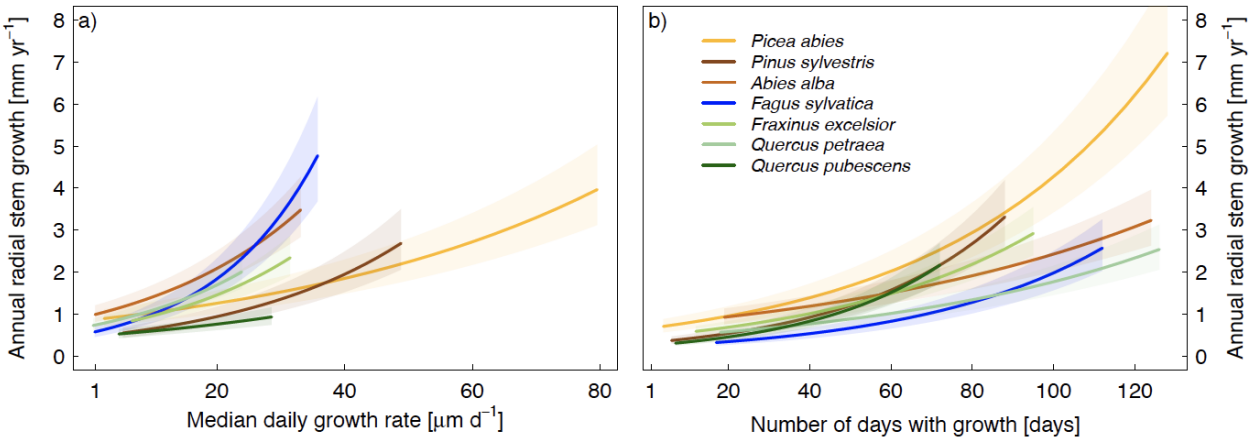

FIGURE S8. Response curves of annual stem growth derived from linear mixed models (LMM). Annual stem growth in relation to a) median daily growth rates, and b) median number of days with growth as derived from LMMs in **Table 2.** Model predictions were made with all predictors being set to their mean, except for the displayed variable, which was varied for the given range of the actual occurring values and back transformed from logarithmic responses. Model performance is given in **Table 2**. Analyses include data of trees that have an annual increment > 0.1 mm yr^{-1}.

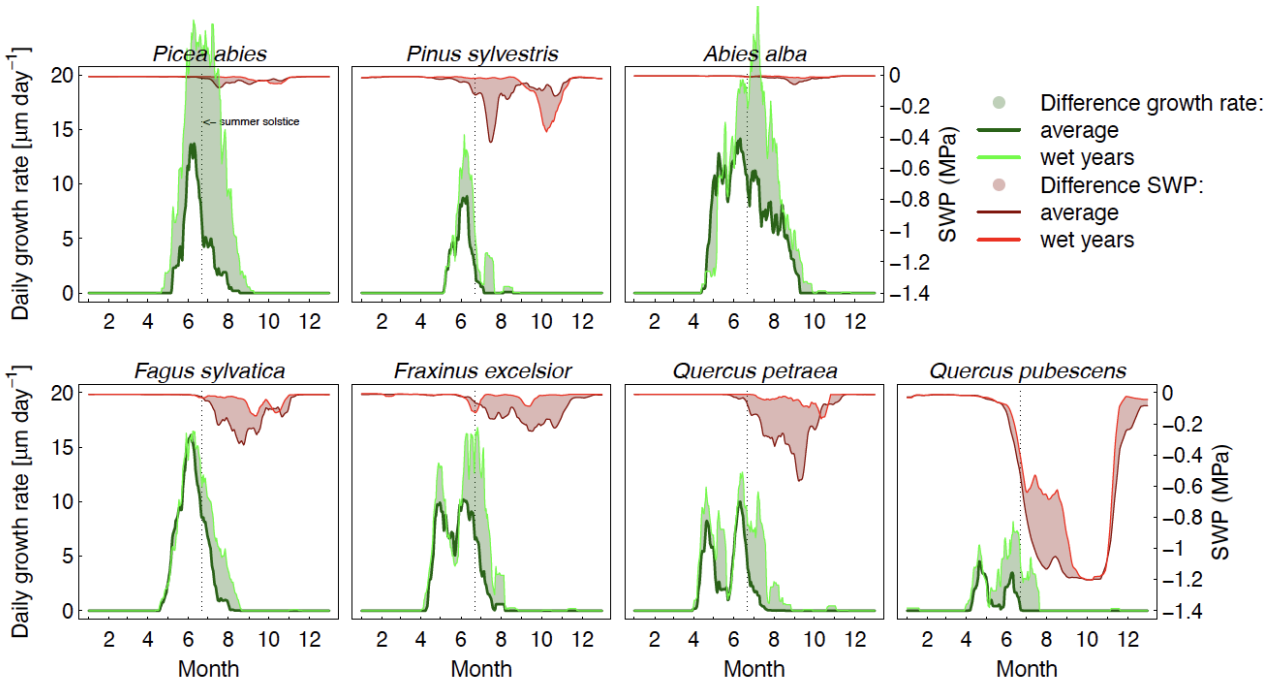

FIGURE S9. Annual course of growth rate and soil water potential in average and only in the moistest years. Displayed are 14-days running means of the daily growth rate and topsoil water potential (SWP), averaged across all sites per species. Moist years are defined per site as years with SWP during April to September below the 25% quantile of SWP from April to September of all measured years. This resulted in one to two moist years per site of totally two to eight (in average six) years of observation per site.