

European beech dieback after premature leaf senescence during the 2018 drought in northern Switzerland

Running Title: Drought effects on European beech

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Supporting Information

Table S1. Mean temperature, precipitation sum and climatic water balance (CWB) for the growing season (April to September) in the three regions Basel (BL), Schaffhausen (SH), and Zurich (ZH) for the years 2018 to 2021 and the climate norm period 1981-2010.

	Temperature [°C]			Precipitation [mm]			CWB [mm]		
	BL	SH	ZH	BL	SH	ZH	BL	SH	ZH
2018	18.6	18.0	17.7	324	414	434	-374	-257	-241
2019	16.7	16.2	16.0	480	514	558	-163	-86	-45
2020	17.6	16.6	16.5	349	392	462	-322	-233	-175
2021	15.8	15.0	14.9	578	688	676	7	144	115
1981-2010	15.9	15.2	15.0	498	534	618	-51	-51	+66

Regional climate data for each site was derived from the nearest weather station: BL: Basel / Binningen, 318 m. ü. M., 47.54°N / 7.58 °E, SH: Schaffhausen, 438 m. ü. M., 47.68 °N / 8.62 °E, ZH: Zürich / Affoltern, 444 m. ü. M., 47.42 °N / 8.51 °E. ©MeteoSwiss.

Table S2. Cumulative percentage of dead and logged trees averaged per tree group (mean \pm 1 SE) of early leaf fall and control trees in the three regions Basel (BL), Schaffhausen (SH) and Zurich (ZH) from 2018 to 2021.

No	Aug 2018		Apr 2019		Aug 2019		May 2020		Aug 2020		Aug 2021	
	dead	logged	dead	logged	dead	logged	dead	logged	dead	logged	dead	logged
BL Early	303	0.0 \pm 0.0	0.0 \pm 0.0	1.0 \pm 0.6	6.6 \pm 2.7	3.3 \pm 1.0	11.8 \pm 3.8	3.9 \pm 1.0	32.2 \pm 5.1	5.6 \pm 1.2	32.5 \pm 5.2	7.2 \pm 1.6
BL Control	92	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	1.1 \pm 1.1	0.0 \pm 0.0	1.1 \pm 1.1	11.6 \pm 6.7	1.1 \pm 1.1	11.6 \pm 6.7	2.1 \pm 1.4
SH Early	300	0.0 \pm 0.0	0.0 \pm 0.0	2.3 \pm 0.8	1.7 \pm 1.1	4.7 \pm 1.2	1.7 \pm 1.1	5.3 \pm 1.3	5.3 \pm 2.2	6.3 \pm 1.5	5.7 \pm 2.3	10.3 \pm 2.0
ZH Early	221	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	2.9 \pm 1.9	3.0 \pm 2.0	2.5 \pm 1.8	3.0 \pm 2.0	3.6 \pm 2.0	3.4 \pm 2.0	3.9 \pm 2.1	3.8 \pm 2.0
ZH Control	47	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	9.1 \pm 9.1	0.0 \pm 0.0	9.1 \pm 9.1	0.0 \pm 0.0	9.1 \pm 9.1	0.0 \pm 0.0	16.4 \pm 11.1	0.0 \pm 0.0
ALL Early	824	0.0 \pm 0.0	0.0 \pm 0.0	1.1 \pm 0.3	3.7 \pm 1.2	3.7 \pm 0.8	5.4 \pm 1.5	4.1 \pm 0.9	14.0 \pm 2.2	5.1 \pm 0.9	14.4 \pm 2.3	7.2 \pm 1.1
ALL Control	139	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	3.3 \pm 3.3	0.7 \pm 0.7	3.3 \pm 3.3	0.7 \pm 0.7	10.7 \pm 5.3	0.7 \pm 0.7	13.3 \pm 5.8	1.3 \pm 0.9
All	963	0.0\pm0.0	0.0\pm0.0	0.7\pm0.5	3.7\pm1.1	2.1\pm0.8	5.1\pm1.4	2.3\pm1.0	13.6\pm2.1	3.0\pm1.3	14.2\pm2.1	4.4\pm1.9
												21.2\pm2.5

No, initial number of trees in August 2018. Dead, Logged, cumulative percentages of dead and logged trees with respect to the initial numbers of trees in this group.

Table S3. Proportion of crown dieback (mean \pm 1 SE) (A), presence of bleeding cankers (B), presence of bark beetle holes (C) and crown transparency (D) of early leaf fall and control trees in the three regions Basel (BL), Schaffhausen (SH) and Zurich (ZH).

	No	Aug 2018	Apr 2019	Aug 2019	Aug 2020	Aug 2021
(A) Crown dieback						
BL Early	178	0.2 \pm 0.1	13.1 \pm 1.4	29.3 \pm 2	35.4 \pm 2.6	23.4 \pm 2.3
BL Control	81	0.0 \pm 0.0	5.2 \pm 0.4	9.4 \pm 0.8	5.1 \pm 1.3	5.3 \pm 1.4
SH Early	249	1.8 \pm 0.3	16.1 \pm 1.4	27.2 \pm 1.8	30.2 \pm 2.2	20.7 \pm 2.0
ZH Early	196	1.2 \pm 0.2	8.0 \pm 0.8	14.8 \pm 1.2	22.3 \pm 2.1	10.4 \pm 1.4
ZH Control	41	0.2 \pm 0.2	3.2 \pm 0.5	5.5 \pm 0.6	3.7 \pm 1	1.3 \pm 0.4
All Early	623	1.2 \pm 0.1	12.7 \pm 0.7	23.9 \pm 1	29.2 \pm 1.3	18.2 \pm 1.1
All Control	122	0.1 \pm 0.1	4.5 \pm 0.4	8.1 \pm 0.6	4.6 \pm 0.9	4.0 \pm 1.0
All trees	745	1.0 \pm 0.1	11.3 \pm 0.6	21.3 \pm 0.9	25.3 \pm 1.2	15.9 \pm 1.0
(B) Bleeding cankers						
BL Early	178	1.7	14.1	22.5	23.2	5.8
BL Control	81	0.0	6.2	12.3	16.0	2.5
SH Early	249	0.4	16.9	24.5	26.3	3.2
ZH Early	196	1.5	16.9	26.5	10.2	4.6
ZH Control	41	0.0	4.9	4.9	0.0	2.4
All Early	623	1.1	16.1	24.6	20.1	4.4
All Control	122	0.0	5.7	9.8	10.7	2.5
All trees	745	0.9	14.4	22.1	18.5	4.1
(C) Bark beetles						
BL Early	178	-	0.0	6.2	23.6	31.5
BL Control	81	-	1.2	3.7	14.8	16.0
SH Early	249	-	1.2	12.9	18.1	20.1
ZH Early	196	-	2.6	6.6	10.7	18.4
ZH Control	41	-	2.4	4.9	9.8	12.2
All Early	623	-	1.3	9.0	17.3	22.8
All Control	122	-	1.6	4.1	13.1	14.8
All trees	745	-	1.3	8.2	16.6	21.5
(D) Crown transparency						
BL Early	178	43.2 \pm 1.3	-	-	52.9 \pm 1.7	34.4 \pm 1.7
BL Control	81	28.5 \pm 1.2	-	-	32.4 \pm 1.7	25.6 \pm 1.3
SH Early	249	44.4 \pm 0.9	-	-	45.0 \pm 1.6	30.1 \pm 1.7
ZH Early	196	39.3 \pm 1.0	-	-	39.2 \pm 1.5	26.2 \pm 1.1
ZH Control	41	27.3 \pm 1.2	-	-	15.1 \pm 2.1	18.3 \pm 1.2
All Early	623	42.4 \pm 0.6	-	-	45.4 \pm 1.0	30.1 \pm 0.9
All Control	122	28.1 \pm 0.9	-	-	26.3 \pm 1.5	23.1 \pm 1.0
All trees	745	39.9 \pm 0.6	-	-	42.4 \pm 0.9	29.0 \pm 0.8

No, number of analyzed trees. ‘-’, no assessments for the respective parameter were made (bark beetle holes in summer 2018, crown transparency in 2019).

Table S4. Average values of explanatory variables (mean \pm 1 SE) of early leaf fall and control trees in the three regions Basel (BL), Schaffhausen (SH) and Zurich (ZH).

	No	Clay content [wt-%]	Competition index [m ⁻¹]	CWB [mm]	DBH [cm]	Forest edge distance [m]	Gravel content [vol-%]	Soil depth [cm]	Soil pH	Tree height [m]
BL Early	178	26 \pm 0.6	1.1 \pm 0.1	-138 \pm 4	44.8 \pm 0.9	78.5 \pm 6.0	36 \pm 0.8	74 \pm 1.8	5.4 \pm 0.1	26.9 \pm 0.3
BL Control	81	28 \pm 0.8	1.2 \pm 0.1	-124 \pm 6	45.6 \pm 1.4	56.8 \pm 5.7	36 \pm 1.0	61 \pm 2.7	5.9 \pm 0.1	29.8 \pm 0.5
SH Early	249	27 \pm 0.2	1.2 \pm 0.0	-202 \pm 1	40.8 \pm 0.7	90.2 \pm 5.3	21 \pm 0.3	63 \pm 1.7	5.1 \pm 0.1	27.8 \pm 0.2
ZH Early	196	21 \pm 0.2	1.1 \pm 0.1	-6 \pm 4	51.0 \pm 1.1	25.3 \pm 2.1	18 \pm 0.2	69 \pm 1.6	5.4 \pm 0.1	29.5 \pm 0.2
ZH Control	41	22 \pm 0.3	0.9 \pm 0.1	7 \pm 7	49.9 \pm 2.0	20.1 \pm 2.0	18 \pm 0.6	67 \pm 2.6	5.2 \pm 0.2	32.2 \pm 0.5
All Early	623	25 \pm 0.2	1.1 \pm 0.0	-122 \pm 4	45.2 \pm 0.5	66.4 \pm 3.0	24 \pm 0.4	68 \pm 1	5.3 \pm 0.1	28.0 \pm 0.1
All Control	122	26 \pm 0.6	1.1 \pm 0.1	-80 \pm 7	47.0 \pm 1.1	44.5 \pm 4.1	30 \pm 1.0	63 \pm 2.0	5.7 \pm 0.1	30.6 \pm 0.4
All trees	745	25\pm0.2	1.1\pm0.0	-115\pm3	45.5\pm0.5	62.8\pm2.6	25\pm0.4	67\pm0.9	5.3\pm0.0	28.5\pm0.1

No, number of analyzed trees. For variable descriptions see Table 1.

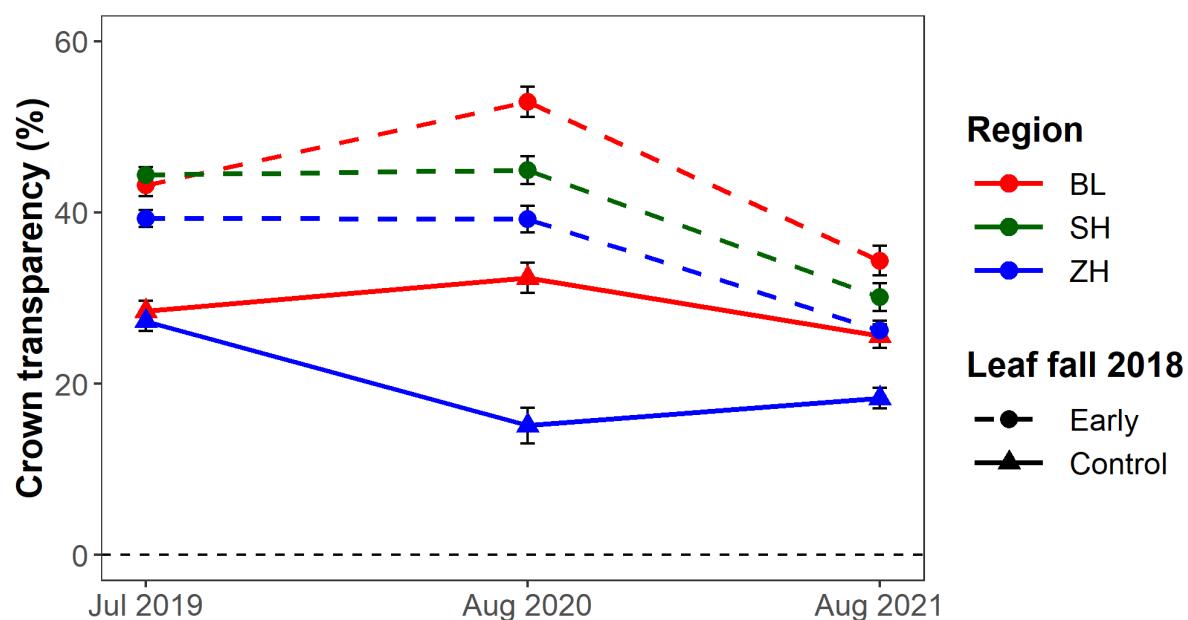


Figure S1. Development of crown transparency (mean \pm SE) in early leaf fall (dashed lines) and control trees (solid lines) in the three regions Basel (BL), Schaffhausen (SH) and Zurich (ZH) in northern Switzerland from 2019 to 2021. Only trees were included that had observations in all surveys ($N = 745$; for numbers see also Supplementary Table S3).