Supplementary Tables

Supplementary Table 1: Detailed statistics for Table 2 of the main text. Post-hoc contrasts were performed using the emmeans-package for R (see Methods). P-values refer to two-sided t-tests without adjustment for multiple testing, as tests were performed to assess individual contribution rather than overall significance.

Species	Δ(end - mid)	df	t	*P*-value
Total	-52.2 ± 2.2	20.8	24.2	<0.001
Relative contribution (% of total)				
Anthoxanthum alpinum Á. & D. Löve	4.6 ± 2.9	36	-1.6	0.130
Carex curvula All. s.str.	-26.4 ± 3.0	36	8.9	<0.001
Helictotrichon versicolor Vill.	7.1 ± 3.0	36	-2.3	0.020
Leontodon helveticus Mérat	-4.6 ± 1.8	36	2.6	0.010
Ligusticum mutellina (L.) Crantz	-6.3 ± 1.3	36	-0.9	<0.001
Potentilla aurea L.	3.4 ± 3.6	36	5.0	0.350
Soldanella pusilla Baumg.	7.4 ± 0.8	36	-8.9	<0.001
Other species*	14.9 ± 4.8	36	-3.1	0.004
Graminoids	-6.8 ± 4.1	36	1.6	0.109
Forbs	6.8 ± 4.1	36	-1.7	0.107

* *Alchemilla pentaphyllea* L., *Geum montanum* L., *Gnaphalium supinum* L., *Homogyne alpina* (L.) Cass., *Leucanthemopsis alpina* (L.) Heywood s.str., *Nardus stricta* L., *Poa alpina* L., *Salix herbacea* L., *Sibbaldia procumbens* L., *Trifolium alpinum* L.

Supplementary Table 2: Percentage decrease in photosynthetic vigour index between the maximum and the last value of the season. Temporal development of photosynthetic vigour index is shown in Figure 4 of the main text. Post-hoc contrasts (two-sided t-tests) were performed using the emmeans-package for R (see Methods).

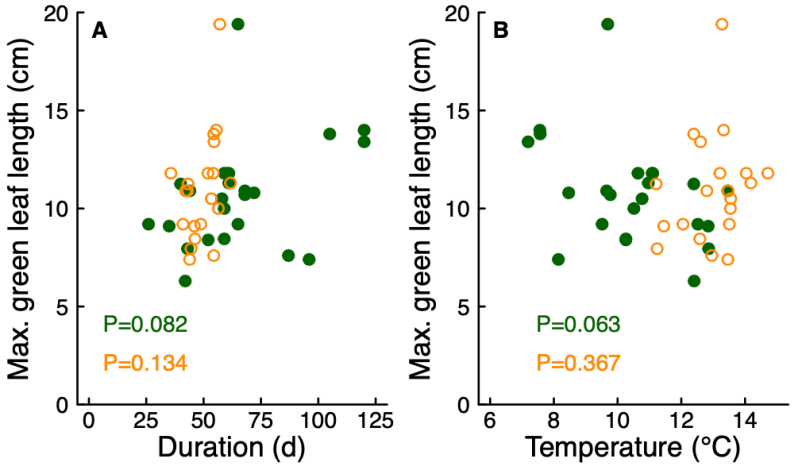
Species	Group	Δ(max - last)	df	t	P
Anthoxanthum	All	69 ± 8	16	8.2	<0.001
	+4m	90 ± 14	16	6.6	<0.001
	+2m	54 ± 14	16	4	0.001
	Field plots	64 ± 16	16	3.9	0.001
Carex	All	79 ± 7	18	10.6	<0.001
	+4m	90 ± 12	18	7.6	<0.001
	+2m	71 ± 12	18	6.1	<0.001
	Field plots	76 ± 15	18	5.1	<0.001
Helictotrichon	All	24 ± 13	9	1.8	0.100
	+4m	1 ± 22	9	0	0.968
	+2m	32 ± 26	9	1.2	0.250
	Field plots	39 ± 20	9	2	0.080
Leontodon	All	58 ± 4	18	14.3	<0.001
	+4m	53 ± 6	18	8.2	<0.001
	+2m	71 ± 6	18	11	<0.001
	Field plots	51 ± 8	18	6.3	<0.001
Ligusticum*	All	100 ± 8	8	12	<0.001
	+4m	100 ± 12	8	8.2	<0.001
	+2m	100 ± 11	8	8.8	<0.001
	Field plots	100 ± 19	8	5.4	0.001
Potentilla	All	38 ± 6	11	6.1	<0.001
	+4m	19 ± 10	11	1.8	0.094
	+2m	49 ± 10	11	4.7	0.001
	Field plots	47 ± 12	11	4	0.002
Soldanella	All	8 ± 15	14	0.5	0.617
	+4m	9 ± 23	14	0.4	0.685
	+2m	2 ± 25	14	0.1	0.936
	Field plots	12 ± 31	14	0.4	0.703

*one-sided t-tests against zero because all leaves died before the end of the season

Supplementary Table 3: Generalized additive models (GAM) for *Carex* leaf elongation and browning at microsites. A thin plate regression spline smoother of k = 4 was assigned to predictor variables. edf = estimated degrees of freedom; DE = deviance explained; MLL = maximum leaf length. Significant variables are presented in bold.

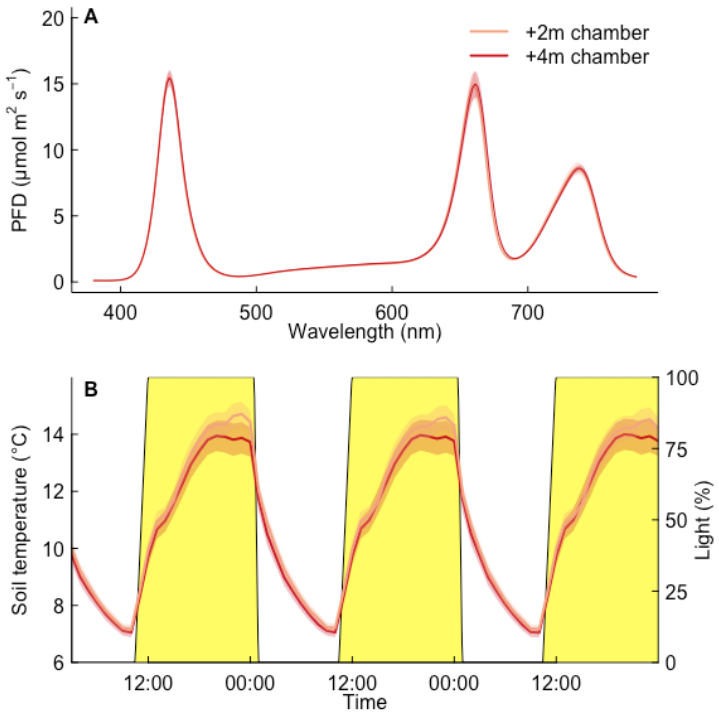
			Smoother				
	Response (Y)	Predictor (X)	n	edf	*P*-value	R^2	DE
Elongation	**Duration (d)**	**Season start (DOY)**	**24**	**2.2**	**<0.001**	**0.96**	**97%**
	Duration (d)	**Mean temperature (°C)**	**23**	**2.7**	**<0.001**	**0.91**	**92%**
	Rate (mm d^{-1})	**Mean temperature (°C)**	**43**	**3.4**	**<0.001**	**0.60**	**63%**
	MLL (cm)	Duration (d)	24	1	0.08	0.09	13%
	MLL (cm)	Mean temperature (°C)	23	1	0.06	0.12	16%
Browning	Duration (d)	Peak leaf length (DOY)	20	1	0.09	0.10	15%
	Duration (d)	Mean temperature (°C)	20	1.7	0.40	0.05	14%
	Rate (mm d^{-1})	Mean temperature (°C)	22	1	0.41	0.00	3%
	MLL (cm)	Duration (d)	20	1.9	0.13	0.19	27%
	MLL (cm)	Mean temperature (°C)	20	1	0.37	0.00	5%

Supplementary Figures

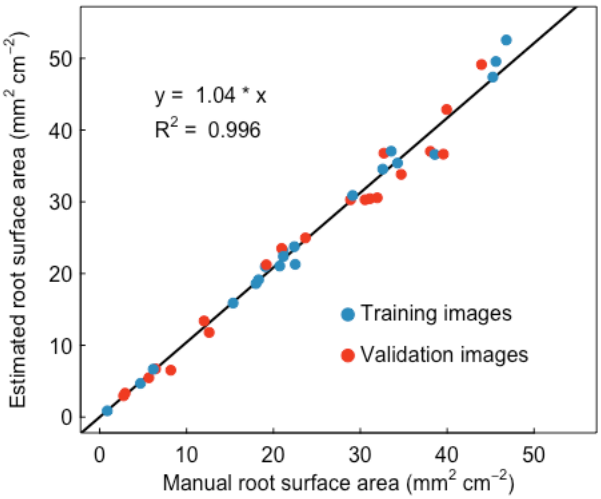


Supplementary Figure 1: Maximum green leaf lengths of *Carex curvula* in microsites. **A)** Maximum green leaf length was unrelated to the duration of leaf elongation (green) and browning (orange, open circles) in *Carex* at microsites. **B)** Maximum leaf length was also unrelated to soil temperature during the periods of elongation and browning. P-values were obtained from F-tests.

Supplementary Figure 2: Overwintering of monoliths in a cold house prior to transferring them to climate chambers. Blankets and wooden boards simulate the load of a snowpack. Digging out monoliths from snow during winter would expose them to unwanted freezing temperatures.



Supplementary Figure 3: Environmental conditions in the two climate chambers. **A)** Light spectra. The two curves (red and orange) overlap to a high degree. **B)** Diurnal pattern of soil temperature (red, measured at 3.5 cm soil depth in monoliths) and light (yellow) for three exemplary days in the climate chambers (daily average of 11 °C). Lines and error bands indicate means ± SE (n = 8 technical replicates in panel A, n = 6 monoliths in panel B for each chamber).



Supplementary Figure 4: Comparison between estimated and manually measured root surface area. Estimated root surface area in 40 automatically segmented images (2550 x 2196 px) that were previously segmented manually. Manual root area was exported from RhizoTrak (v 1.3). Two images (of 42) were not included, because manual root area was not available. Estimated root area was acquired using the software RhizoVision (v 2.0.3) on binary images (roots black, background white) generated by the convolutional neural network.