Subalpine and alpine vegetation under pressure

Consequences of a changing climate in a changing world

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Changing preconditions for plant life...

- Chemistry of the atmosphere (CO$_2$, NO$_x$, dust, ...)
- Climate (temperature, cloud cover, distribution, amount, and time of precipitation, extreme winds)
- Land use (traditional vs. „modern“)
...have impacts on plant life, especially on

- Soil structure and chemistry
- Organisms at the individual and species level
- Phytocoenoses, their composition and stability
- ...and on Man
Crucial changes for mountain plants

- Elevated CO$_2$ level
- Temperature increase: → → → Glacier retreat, prolongation of the vegetation period...
- Changing distribution of precipitation (time and amount)
Siliceous Alps and their elevational belts

Reisigl, H., and Keller, R., 1994
The „alpine belt“ in the European mountains:

Its elevation depends on the geographic position of the mountain range (Ozenda 1988)
Precipitation in the montane belt of the Alps:
Tyrolean Alps in the nineteen fifties: Precipitation and temperature distribution in different altitudinal and latitudinal positions in a N-S-transect
Tyrolean Alps in the nineteen fifties:
Precipitation and temperature distribution in different altitudinal and latitudinal positions in a N-S-transect

Long term measurements show that the outer southern ranges reveal higher temperatures but less precipitation than the northern ranges; the central areas are comparably „warm“ but dry.
Wind-Snow-Ecogram

(H. Aulitzky, 1985, CBl. f. ges. Forstwes. 102/2: 55-77)
From Klug-Pümpel B., 1982, *Vegetatio* 48, 249-254
Morphological traits of alpine plants compared to their relatives in the lowlands
Even individuals of the same species look different at different altitudes.

See more in: Larcher W., 1995, Physiological plant ecology.
Surface temperatures of *Primula minima* (Alps) at different times of a summer day


See also: C. Körner 2003, Alpine Plant Life. Springer
Espeletia schultzii (Andes): Surface temperature of plant organs and soil at noon

Eco-physiological traits

- Photosynthesis, respiration
- Stress hardiness – avoidance
- Phenological reactions
Figure 2. Idealised hypothetical changes of a fluctuating parameter in time and direction.

Körner C. 2001:
Gas exchange of *Carex curvula*

(From C. Körner (1982), *Oecologia* 53: 98-104)

Fig. 2. CO$_2$ exchange in *Carex curvula* under various light and temperature conditions in the field. The data points for dark respiration represent mean values for each of the selected temperature classes. All values are steady state readings after at least 15 min of equilibration at a certain combination of light and temperature.
Fig. 4. The limitation of CO$_2$ uptake of Carex curvula at its natural alpine habitat. The potential net photosynthetic yield under hypothetically optimal climatic conditions is set equal to 100%. The expected net photosynthetic yield for 1976 corresponds to the sum given in Table 4. Further explanation in the text.
Carex curvula grassland

Gas exchange in open top chambers under natural and fertilized conditions and at different CO$_2$ levels

From M. Diemer, 1994,
Oecologia 98: 429-435

Fig. 1 a, b NCE$_{max}$ as a function of mean $p_a$ in the OTCs during gas exchange measurements at treatment (=growth) and short-term reversed CO$_2$ $p_a$. Means and SE of 4–12 OTCs per treatment are plotted. a Responses of unfertilized plots; b fertilized plots. (G: NCE$_{max}$ determined at growth CO$_2$ $p_a$)
Stress resistance

- *Arabis alpina*
- *Poa alpina*
- *Leucanthemopsis alpina*
- *Trifolium badium*
Heat tolerance

TL50 of fertilized and unfertilized alpine plant seedlings grown in the greenhouse

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>TL50 (°C)</th>
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<tbody>
<tr>
<td>Poa alpina</td>
<td></td>
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<tr>
<td>Trifolium badium</td>
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<td>Arabis alpina</td>
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<tr>
<td>Leucanthermopsis alpina</td>
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</table>

- Unfertilized March
- Fertilized March
- Unfertilized June
- Fertilized June
Illustration 1: Temperature changes and selected growth parameters dependent on altitude (after Krautzer & Wittmann 2005)
Reproductive phenology and seed development

Fig. 3. Sequence of reproductive phenophases of populations P1, P2 and P4 in 1993. The phenological dates of the populations P3 and P4 are similar. Phenophases: (a) flower buds visible, (b) anthesis, (c) wilting of petals and fruit elongation, (d) fruit maturation, (e) fruit dehiscence and seed dispersal. Dotted line in P1: mowing time.
Fig. 5. Different proportions of normally developing ovules (seed set), anomalous prezygotic ovules and abortive ovules of the investigated populations of *G. caucasea*.
Diaspore traits and dispersal

- Shape
- Dispersal mode
- Dispersal date
- Longevity of seeds
Seed shapes influence $V_{\text{term}}$

From: Tackenberg O., Stöcklin, J.
2008:
Wind dispersal of alpine plant species.


Germination and juvenile development of alpine plants under cool and warm summer temperature conditions (climate chamber experiment)
Also in alpine grasslands, different strategy types and life traits can be found.

See Grime J.P. 1979, Plant strategies and vegetation processes.
Strategy types of plant species...

- C: competitors
- S: stress tolerators
- R: ruderals
- CS, CSR, SR,…: intermediate types

Growth forms and life spans

Plant functional groups
Early, mid, late colonizers,…
Hohe Tauern, Austria:
Phytomass harvests in alpine grassland throughout the growing season
Phytomass of alpine plant communities is concentrated near the ground.

Angles of leaves inserted in low plant parts are much smaller than leaf angles in the upper plant parts.

Short-term reactions of two alpine communities to temperature rise

**Fig. 2.** Daily temperature variations in OTC- and control plots (9 August 2003), measured 2 cm above (air) and 2 cm below (soil) the soil surface. *Carex sempervirens* community: \( \bar{x}_{\text{OTC}} \text{(air)} = 19.3, \bar{x}_{\text{control}} \text{(air)} = 18.2, U = 3558, p = 0.006**; \( \bar{x}_{\text{OTC}} \text{(soil)} = 17.1, \bar{x}_{\text{control}} \text{(soil)} = 16.7, U = 3899, p = 0.066 \text{ns.} \) *Carex firma* community: \( \bar{x}_{\text{OTC}} \text{(air)} = 17.1, \bar{x}_{\text{control}} \text{(air)} = 15.9, U = 3724, p = 0.022*; \( \bar{x}_{\text{OTC}} \text{(soil)} = 14.8, \bar{x}_{\text{control}} \text{(soil)} = 14.2, U = 3670, p = 0.015*. Abbreviations: \( \bar{x} \), mean; \( U \), \( U \)-value (\( U \)-test); \( p \), \( p \)-value (*\( p < 0.05; **p < 0.01; \text{ns} = \text{not significant.} \)**

From T. Kudernatsch et al. 2008: Short-term effects of temperature enhancement on growth and reproduction of alpine grassland species. BAE 9,263-274 (Field experiment with OTC at Berchtesgaden, Germany)
Growth and reproduction of *Caricetum cuvulae* and *Caricetum firmae* plants

National Park Berchtesgaden, Germany

(Kudernatsch 2008)

Fig. 3. Effects of temperature enhancement on growth and reproduction (top), different life stages (middle) and different growth forms (bottom). *Abbreviations: N, number of samples, \( \bar{x} \), mean, s, standard deviation, U, U-value (U-Test), sign., level of significance (*\( p<0.05 \); **\( p<0.01 \); ***\( p<0.001 \); ns = not significant)*.
All these factors contribute to the specific reaction of a plant community to environmental conditions.