Subalpine and alpine vegetation under pressure

Consequences of a changing climate in a changing world

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Changing preconditions for plant life...

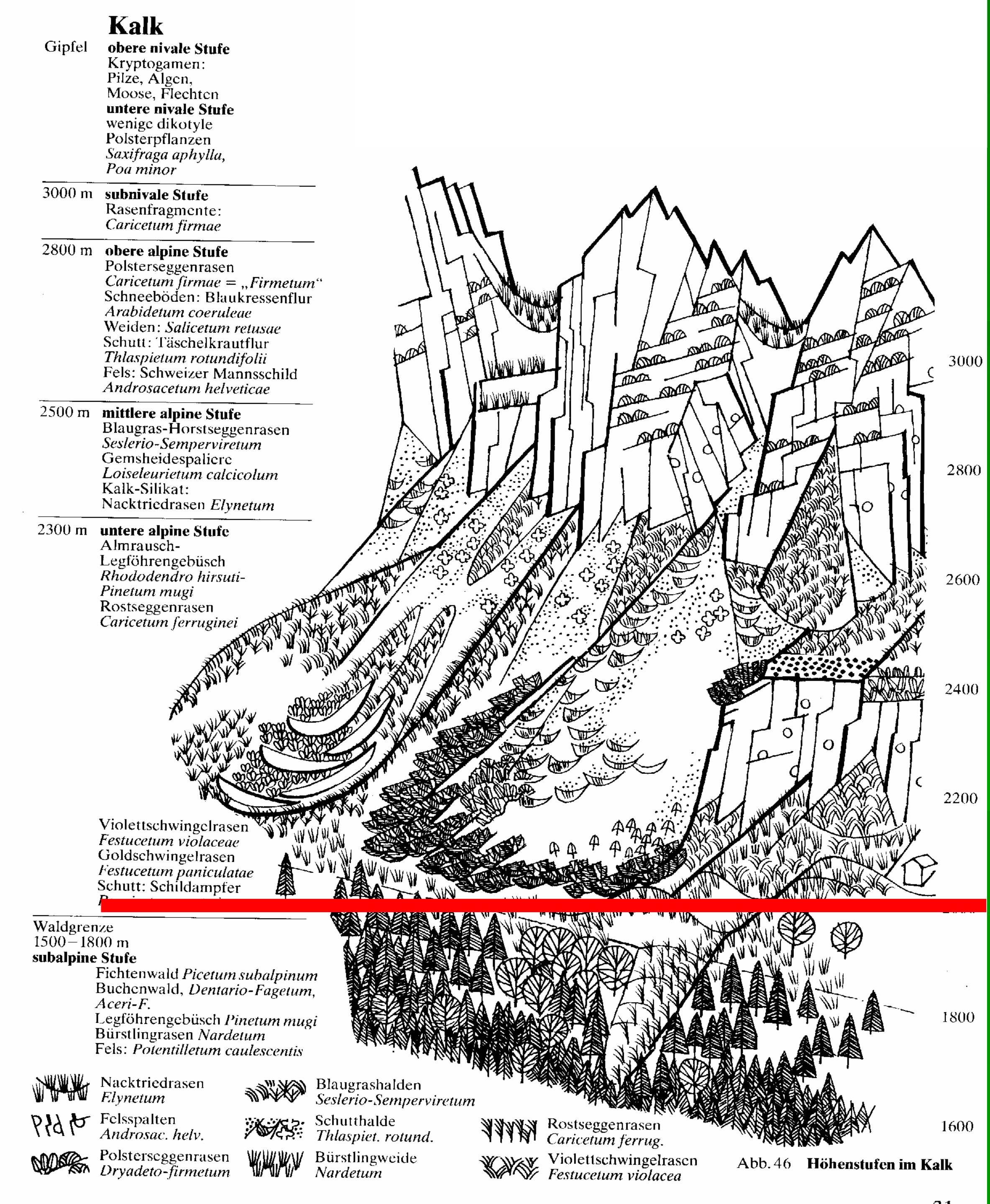
- Chemistry of the atmosphere (CO_2, NO_x, dust,…) →→→
- Climate (temperature, cloud cover, distribution, amount, and time of precipitation, extreme winds) →→→
- Land use (traditional vs. „modern“)

…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

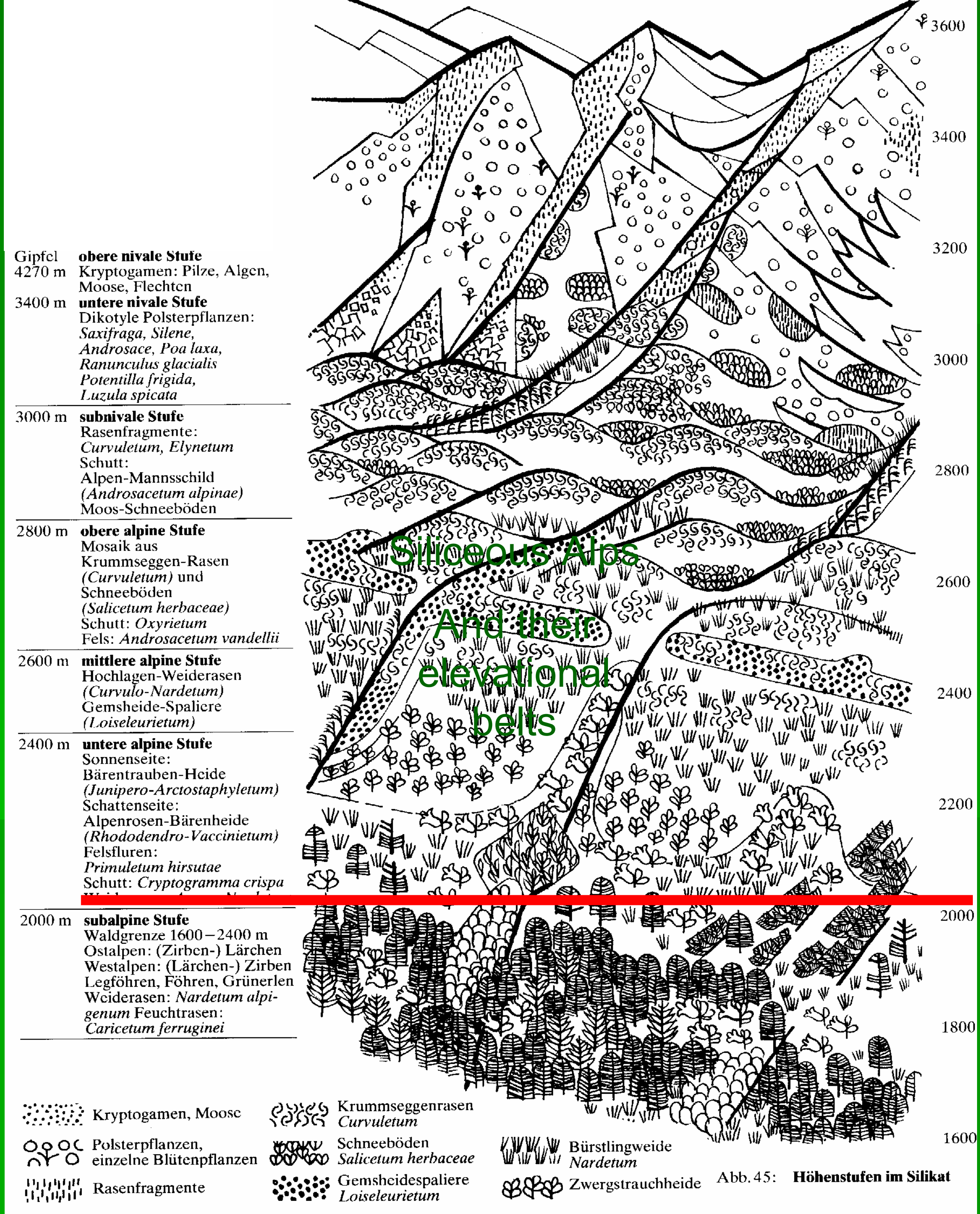
- Elevated CO_2 level
- Temperature increase: → → → Glacier retreat, prolongation of the vegetation period…
- Changing distribution of precipitation (time and amount)



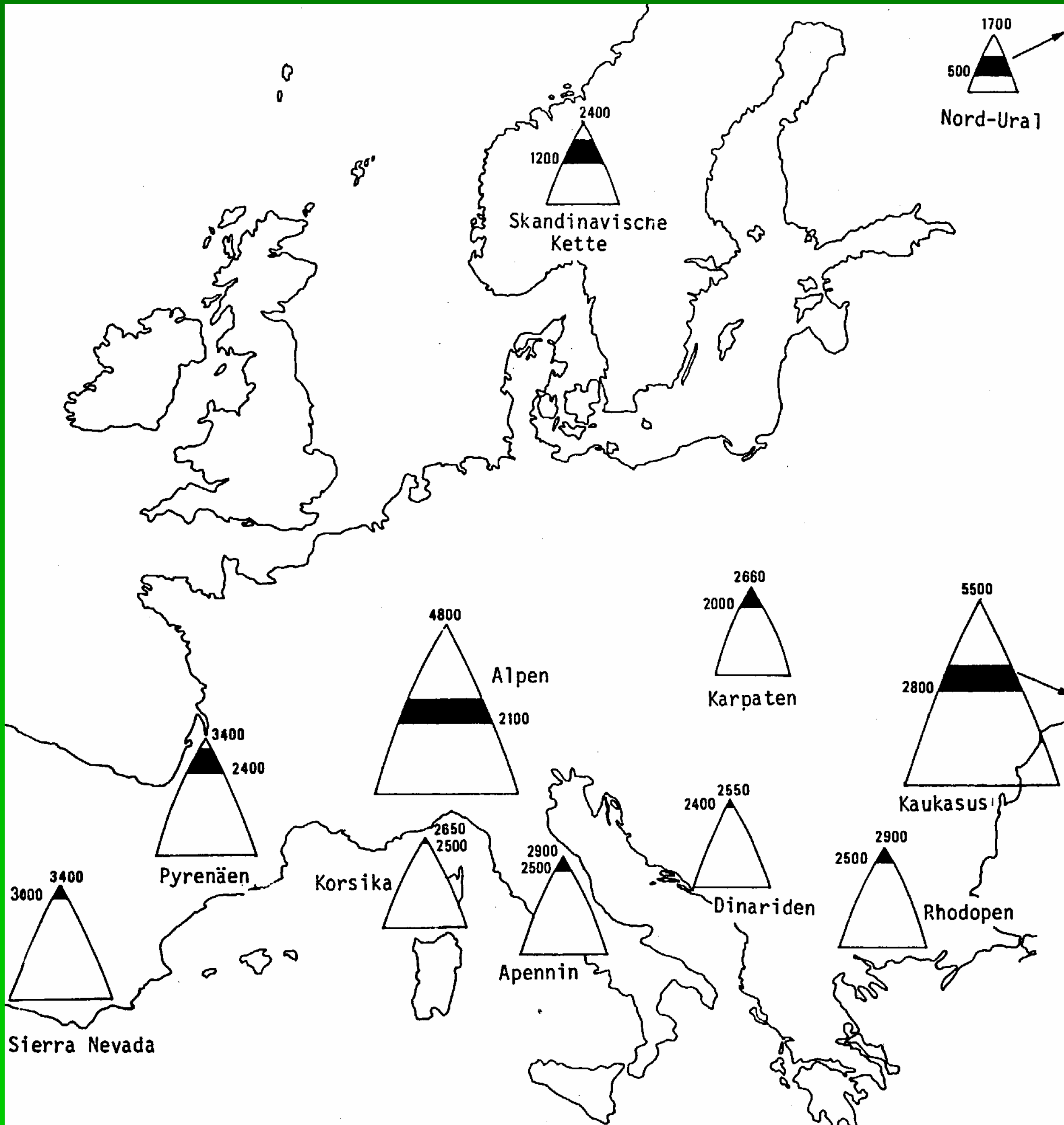
Calcareous Alps

See Reisigl, H., and Keller, R., 1994: Alpenpflanzen im Lebensraum. Fischer

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)

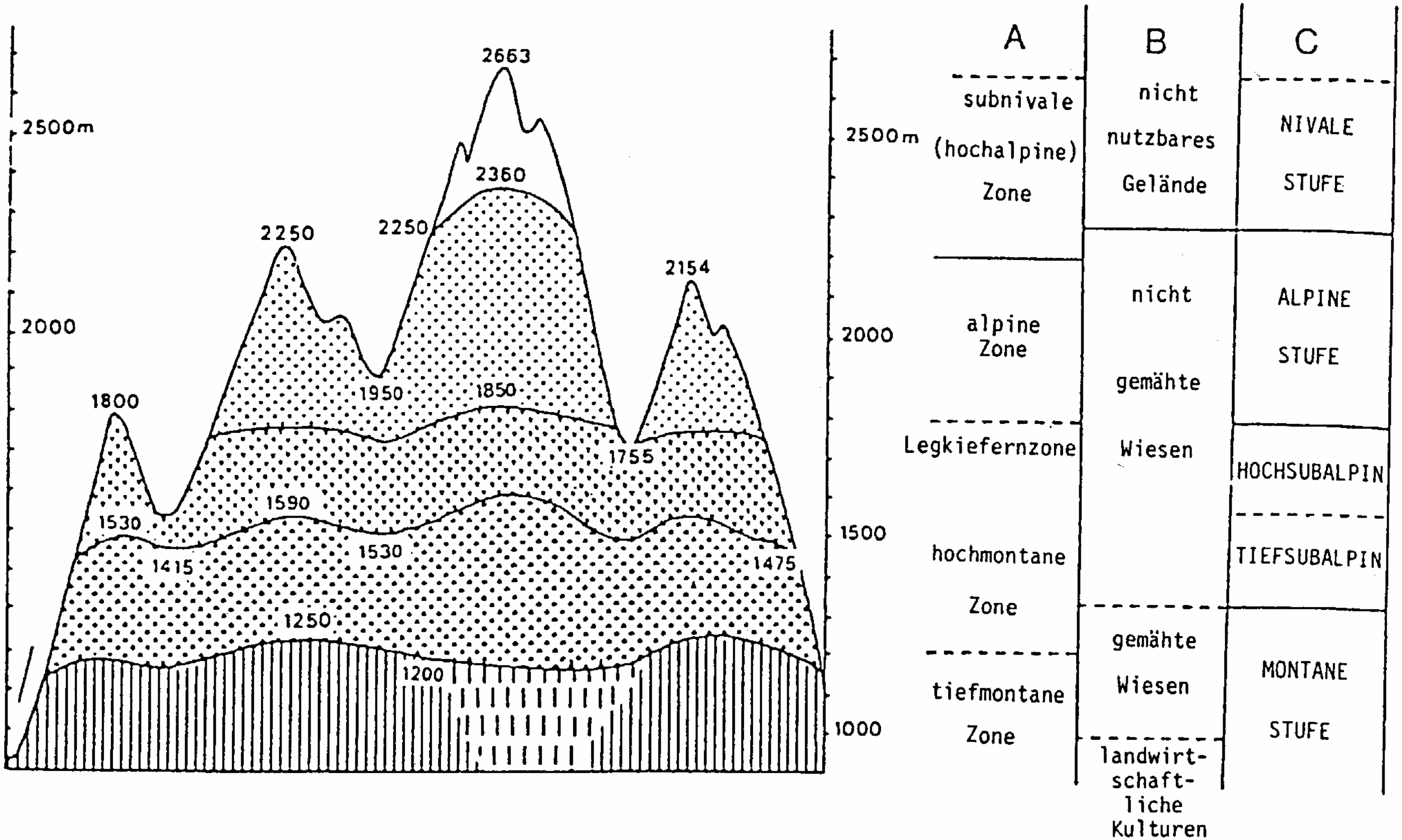
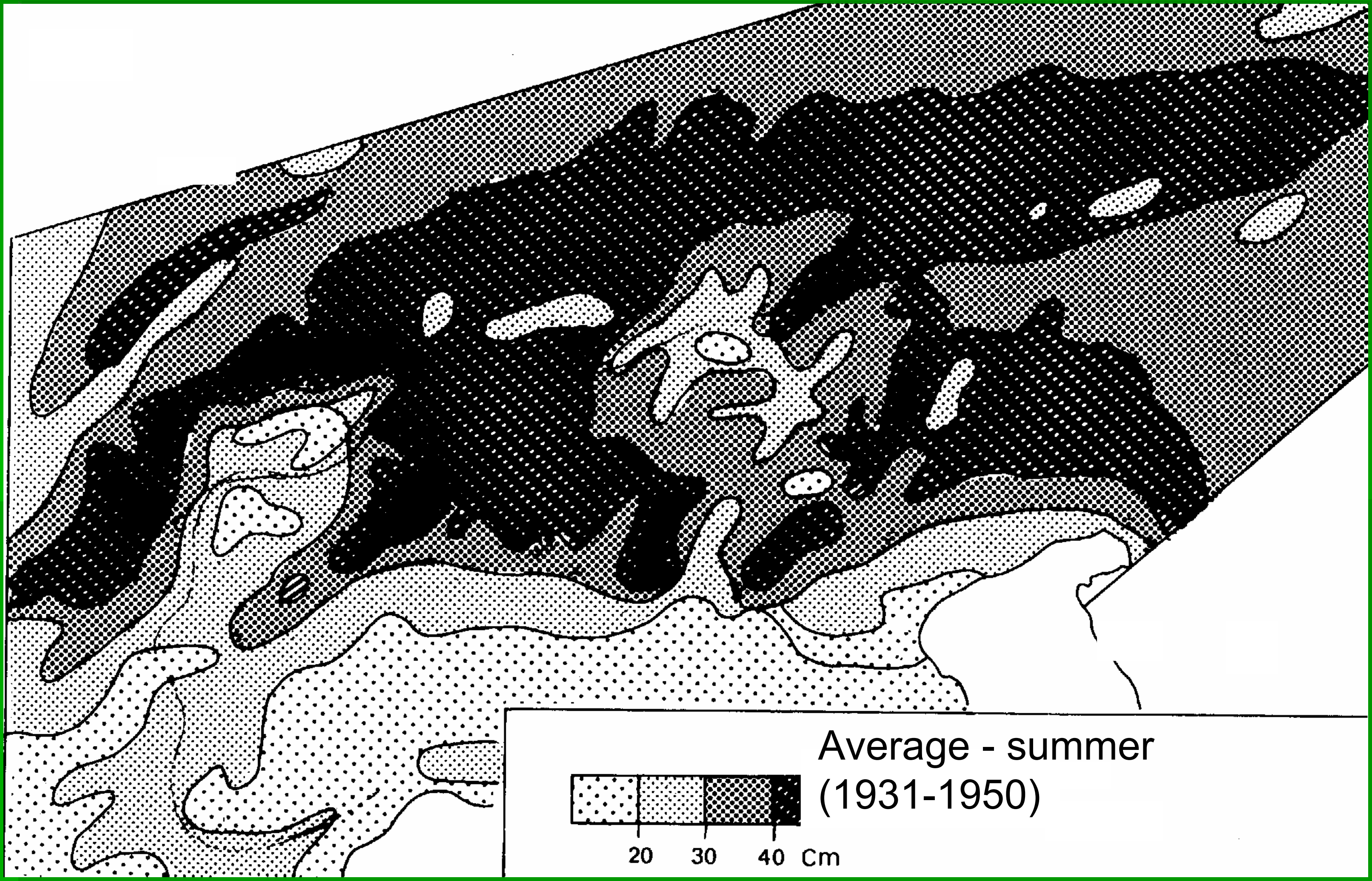


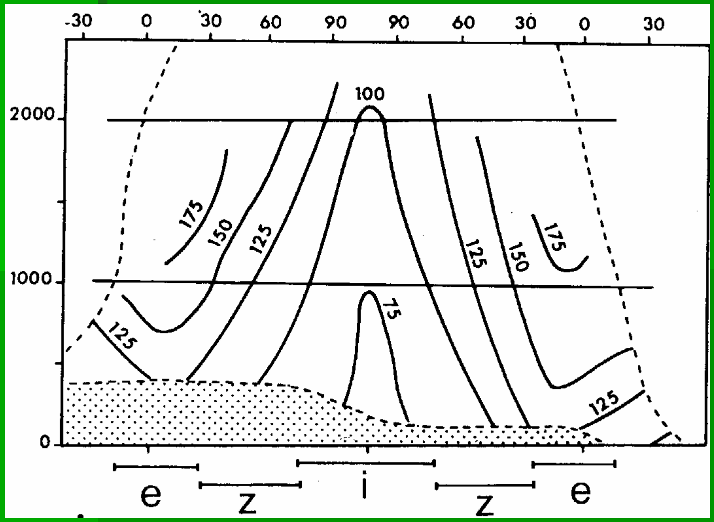
Abb. 12.12: Vegetationsstufung in der Hohen Tatra. Links, Abbildung von PAWŁOWSKI, in WOJTERSKI 1978; A) Höhenstufung durch diese Autoren; B) Landnutzung durch den Menschen in den verschiedenen Höhenlagen; C) vorgeschlagene Nomenklatur als Grundlage für einen Vergleich mit den Alpen.

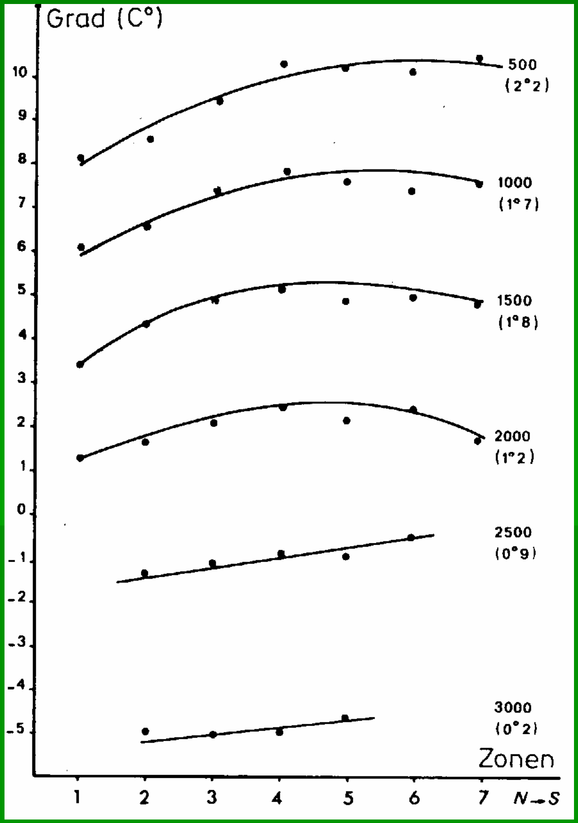
Precipitation in the montane belt of the Alps:



Tyrolean Alps in the nineteen fifties:

Precipitation and temperature distribution in different altitudinal and latitudinal positions in a N-S-transect





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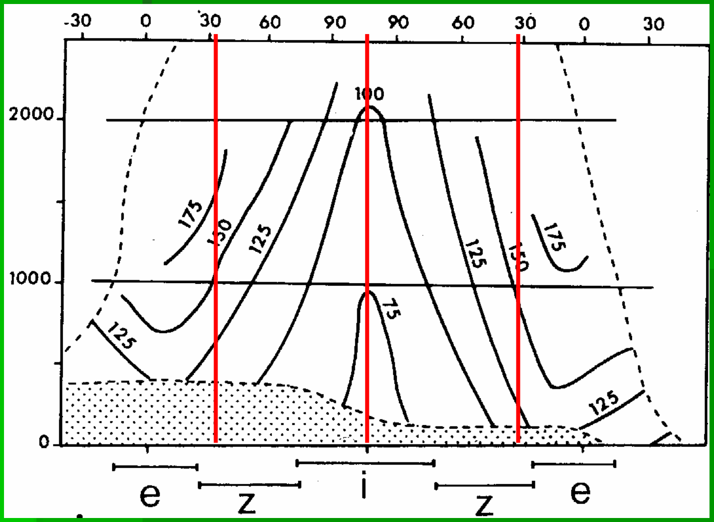
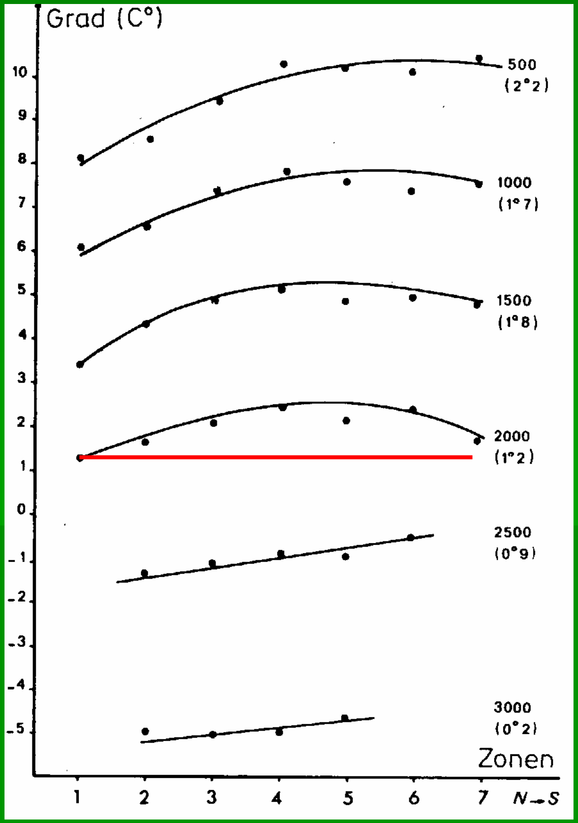
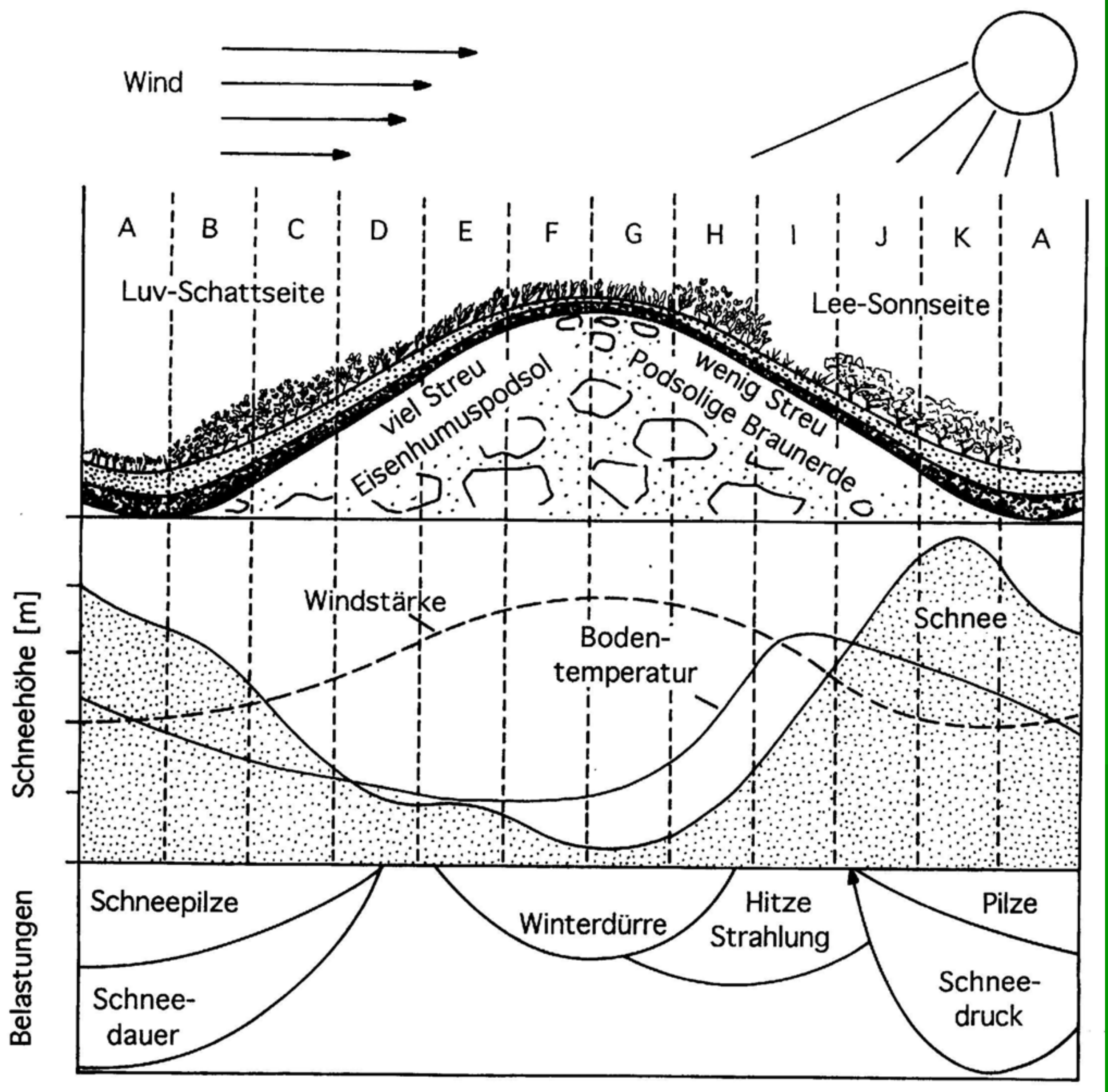




Long term measurements show that the outer southern ranges reveal higher temperatures but less precipitation than the northern ranges; the central areas are comparably „warm“ but dry



Wind-Snow-Ecogram

(H. Aulitzky, 1985, CBl. f. ges. Forstwes. 102/2: 55-77)

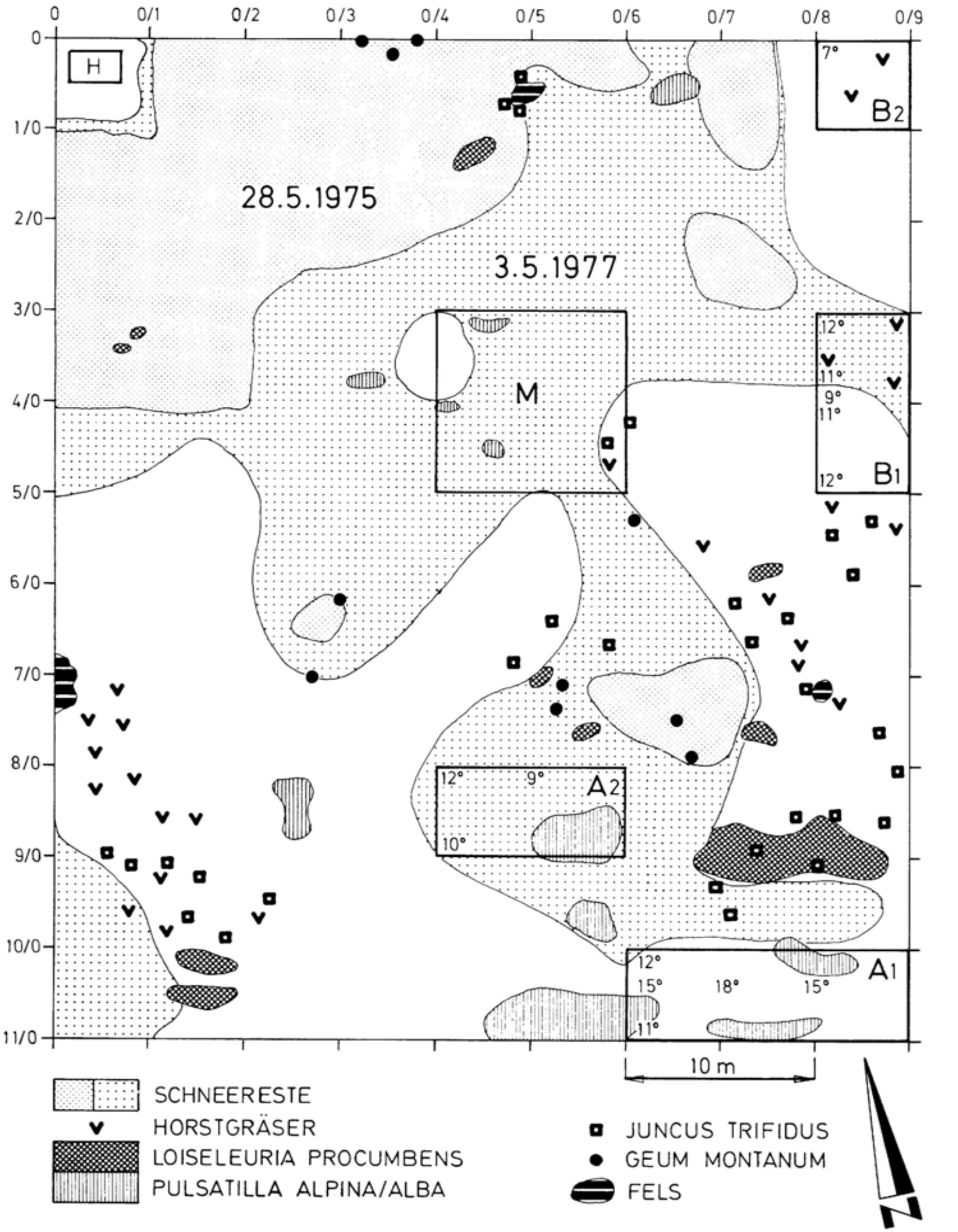
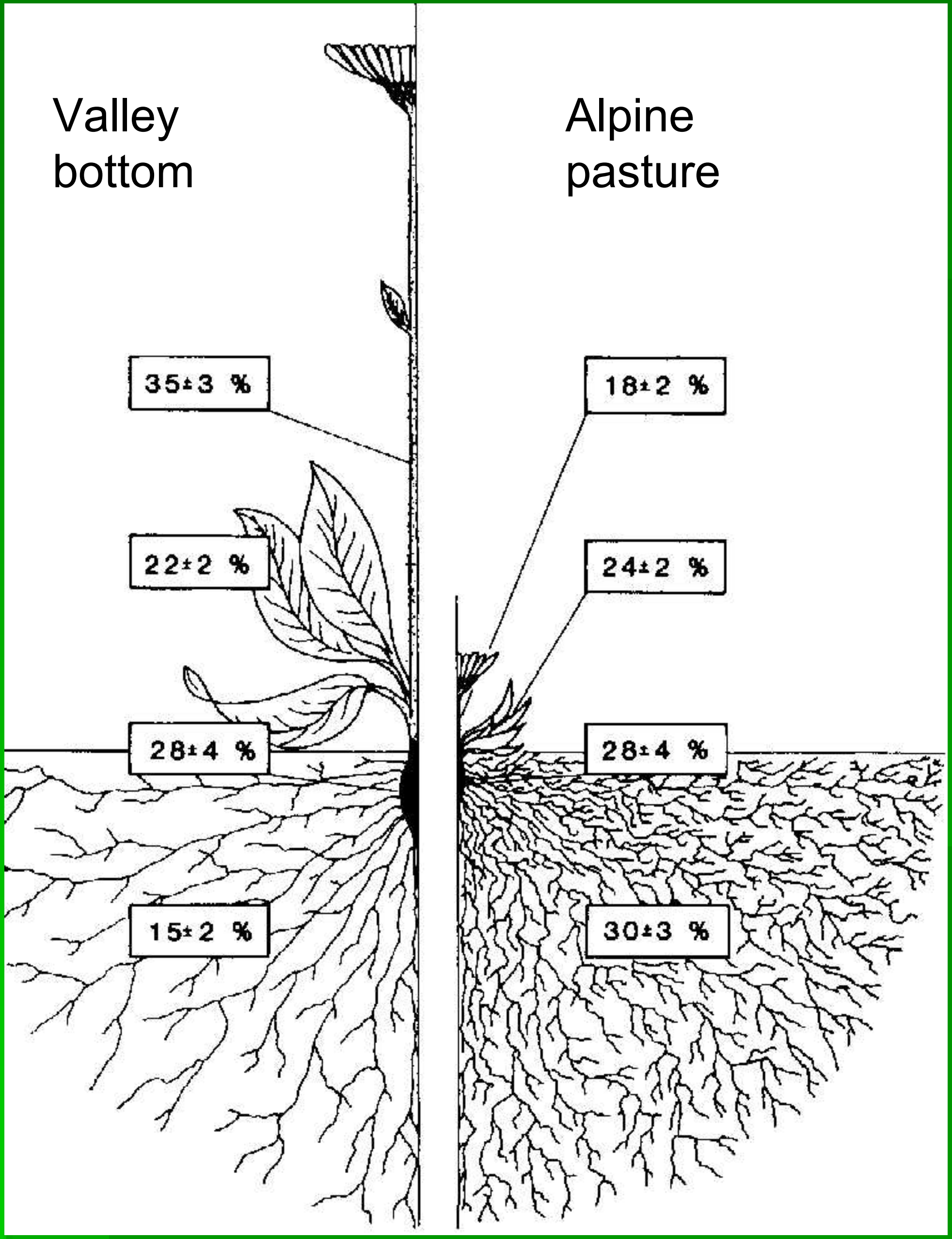


Abbildung 1: Versuchsfläche „*Curvuletum* 2.300 m".

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

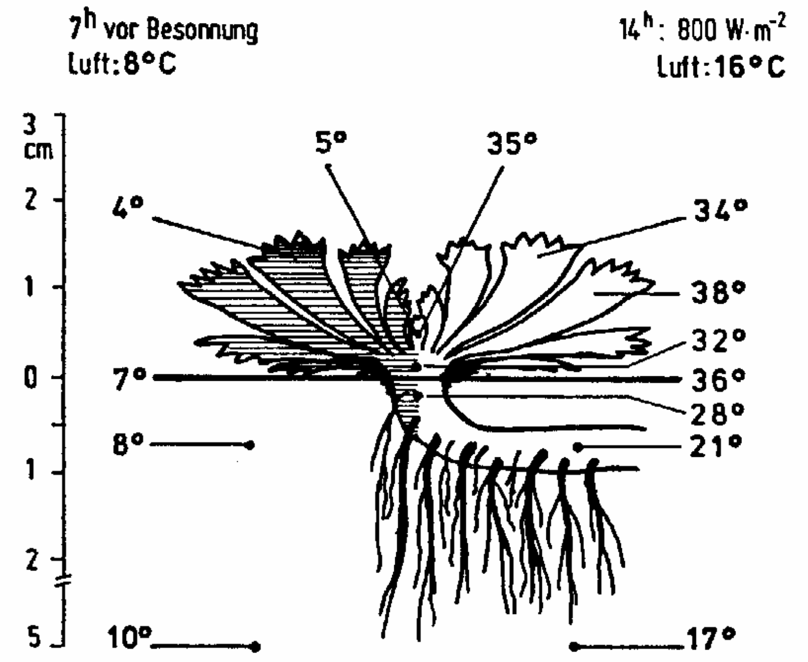


Abb. 2: Tageszeitliche Temperaturamplitude im Sproß- und Wurzelbereich einer Rosettenpflanze (*Primula minima*, siehe Farbtafel I) der alpinen Stufe der Zentralalpen an einem wolkenlosen Augusttag. Nach Messungen von W. Larcher.

See also: C. Körner 2003, Alpine Plant Life. Springer

Espeletia schultzii (Andes): Surface temperature of plant organs and soil at noon

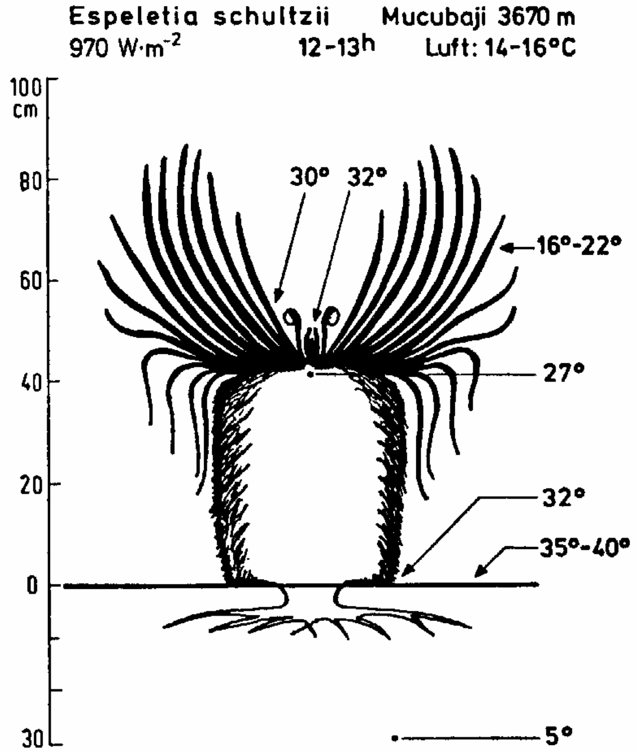


Abb. 3: Temperaturverteilung in einer Großrosettenpflanze der tropischen Anden bei zenitalem Sonnenstand und klarem Himmel. Die weißfilzig behaarten, stark reflektierenden Blätter umgeben wie ein Parabolspiegel den Vegetationsscheitel und die wärmebedürftigen Blütenanlagen. Im Inneren des Blattschopfes tritt ein ähnlicher Überwärmungseffekt wie bei bodenanliegenden Rosettenpflanzen auf. Dadurch sind Wachstum und Blütenentwicklung auch bei ganzjährig niedrigen Temperaturen möglich. Aus LARCHER (1975). Vgl. Farbtafel I.

Eco-physiological traits

- Photosynthesis, respiration
- Stress hardiness – avoidance
- Phenological reactions

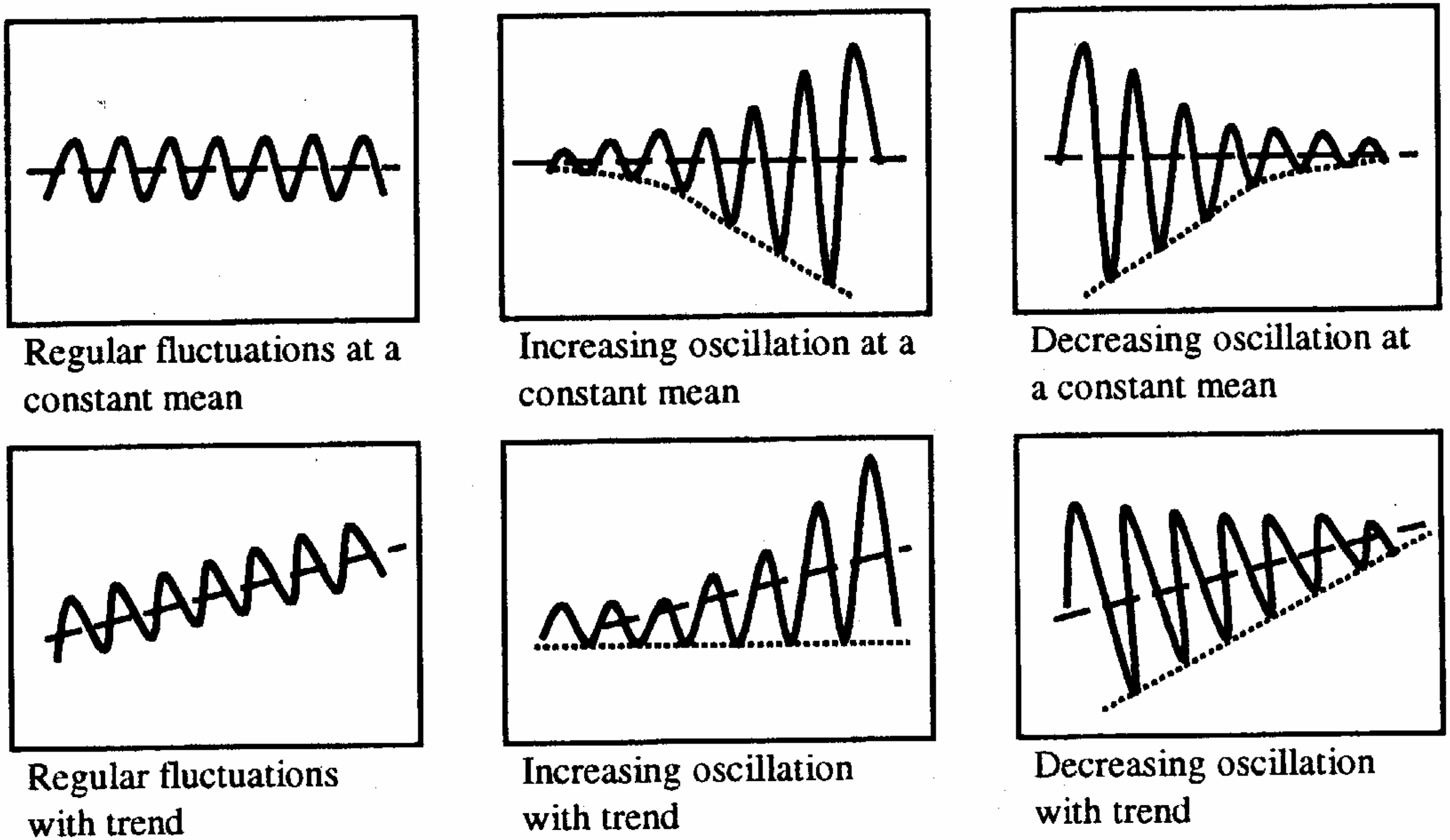


Figure 2. Idealised hypothetical changes of a fluctuating parameter in time and direction.

Körner C. 2001:

In: Walther et al.: „Fingerprints“ of climate change; Kluwer New York

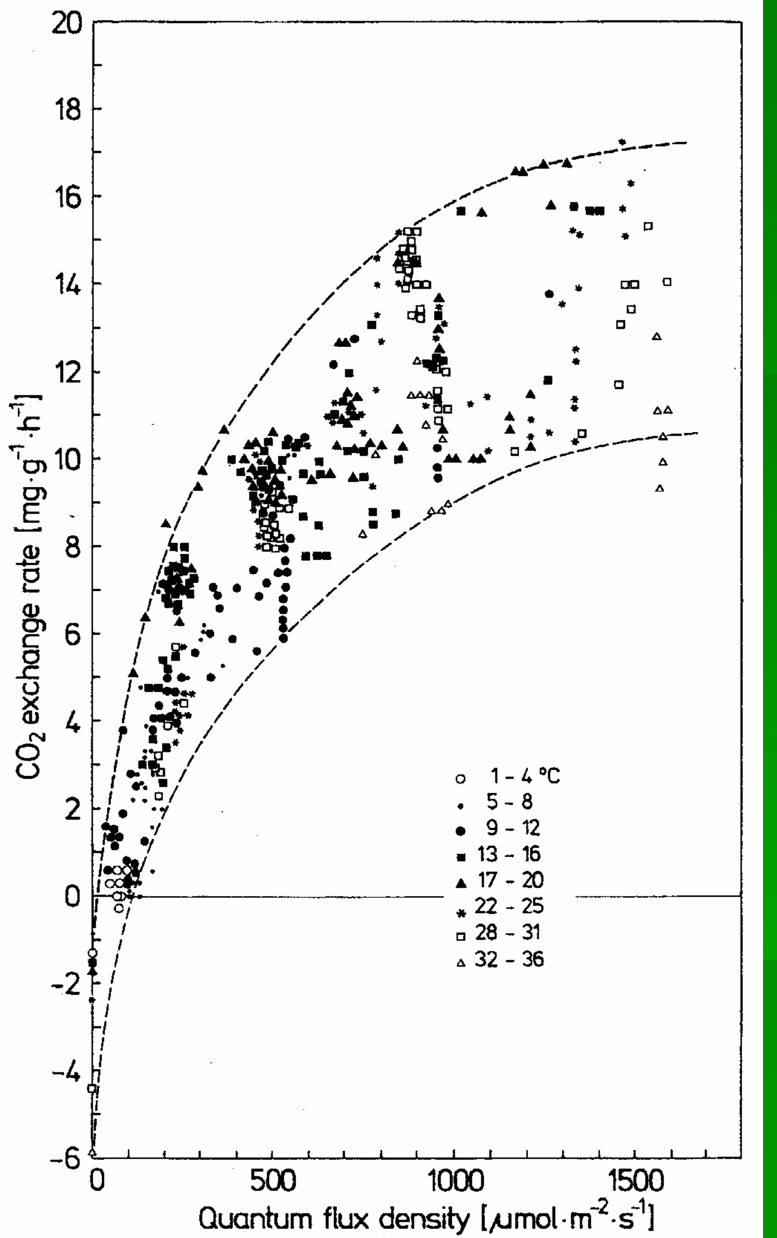


Fig. 2. CO_2 exchange in *Carex curvula* under various light and temperature conditions in the field. The data points for dark respiration represent mean values for each of the selected temperature classes. All values are steady state readings after at least 15 min of equilibration at a certain combination of light and temperature

Gas exchange of *Carex curvula*

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

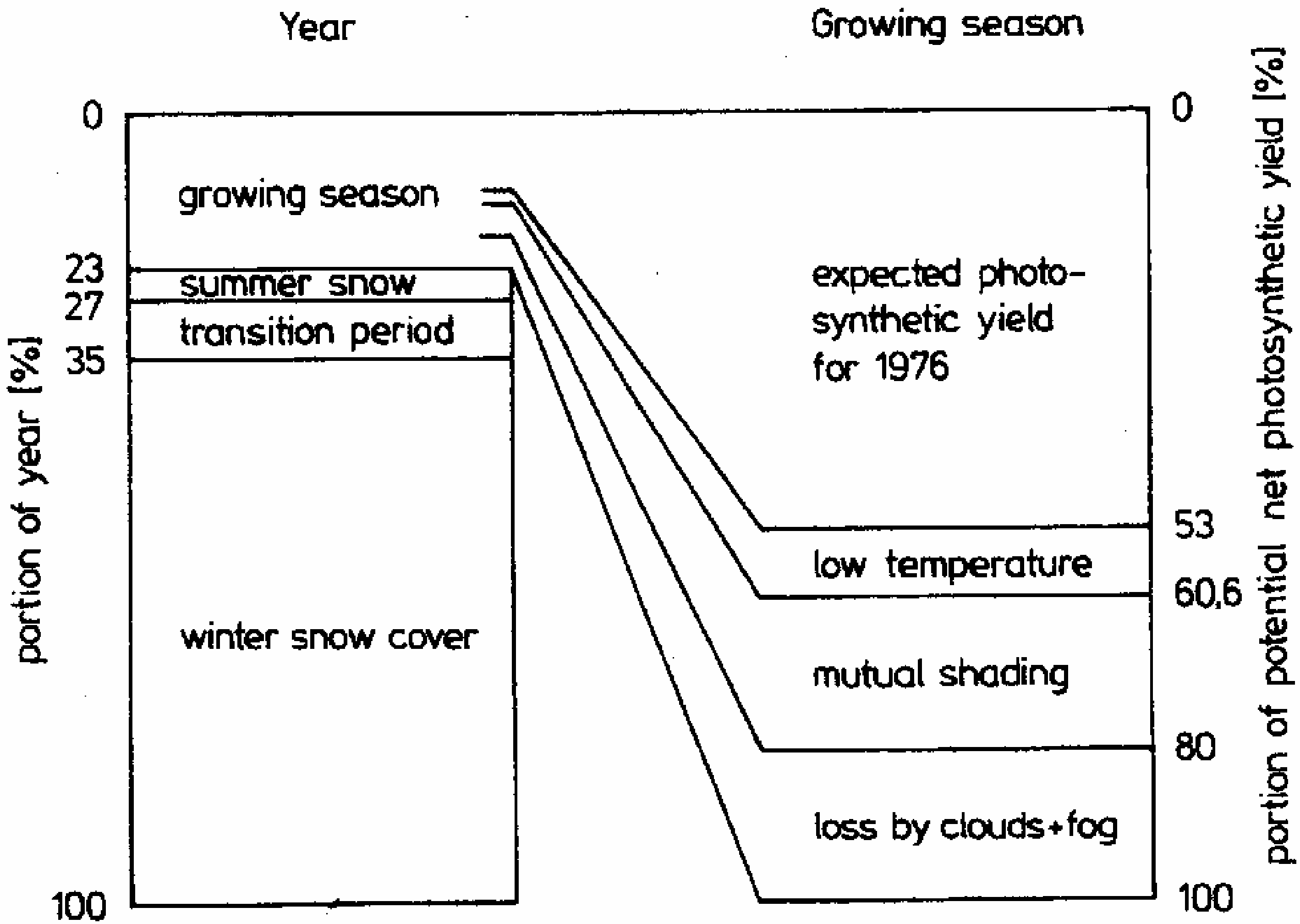


Fig. 4. The limitation of CO_2 uptake of *Carex curvula* at its natural alpine habitat. The potential net photosynthetic yield under hypothetically optimal climatic conditions is set equal to 100%. The expected net photosynthetic yield for 1976 corresponds to the sum given in Table 4. Further explanation in the text

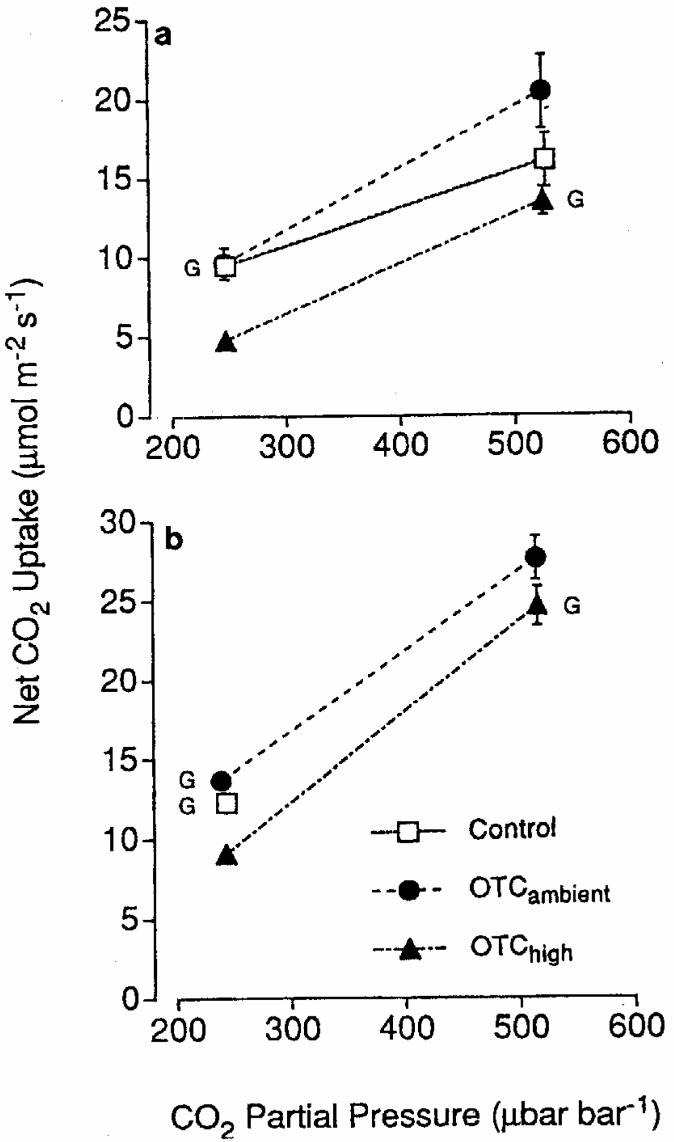


Fig. 1 a,b NCE_{max} as a function of mean p_a in the OTCs during gas exchange measurements at treatment (=growth) and short-term reversed CO_2 p_a. Means and SE of 4–12 OTCs per treatment are plotted. **a** Responses of unfertilized plots; **b** fertilized plots. (*G*: NCE_{max} determined at growth CO_2 p_a)

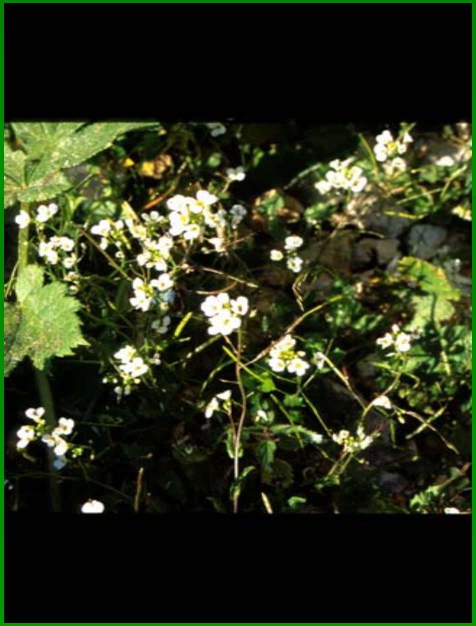
Carex curvula grassland

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

Stress resistance



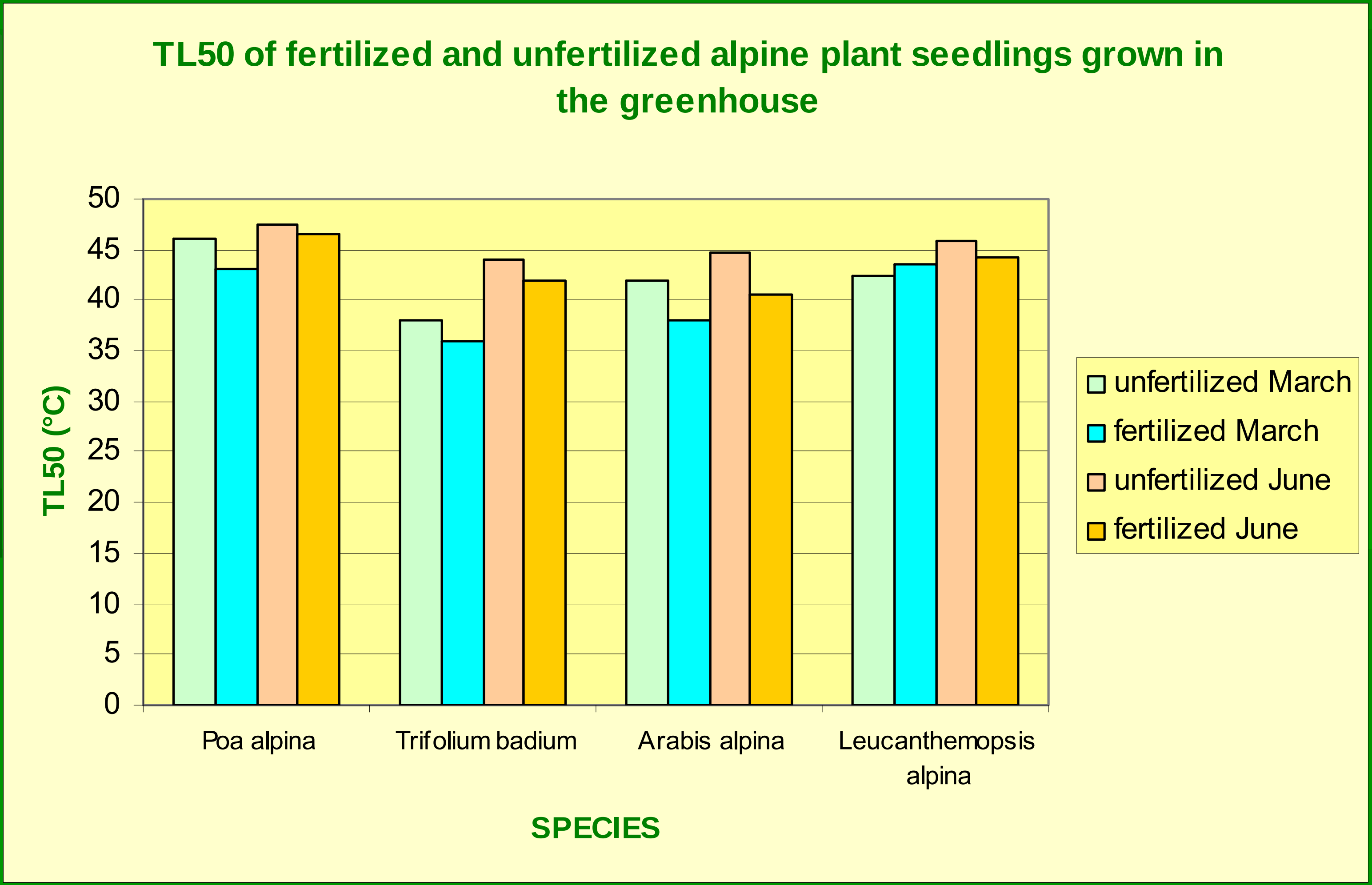
Arabis alpina

Leucanthemopsis alpina

Poa alpina

Trifolium badium

Heat tolerance



Phenology of *Poa alpina*

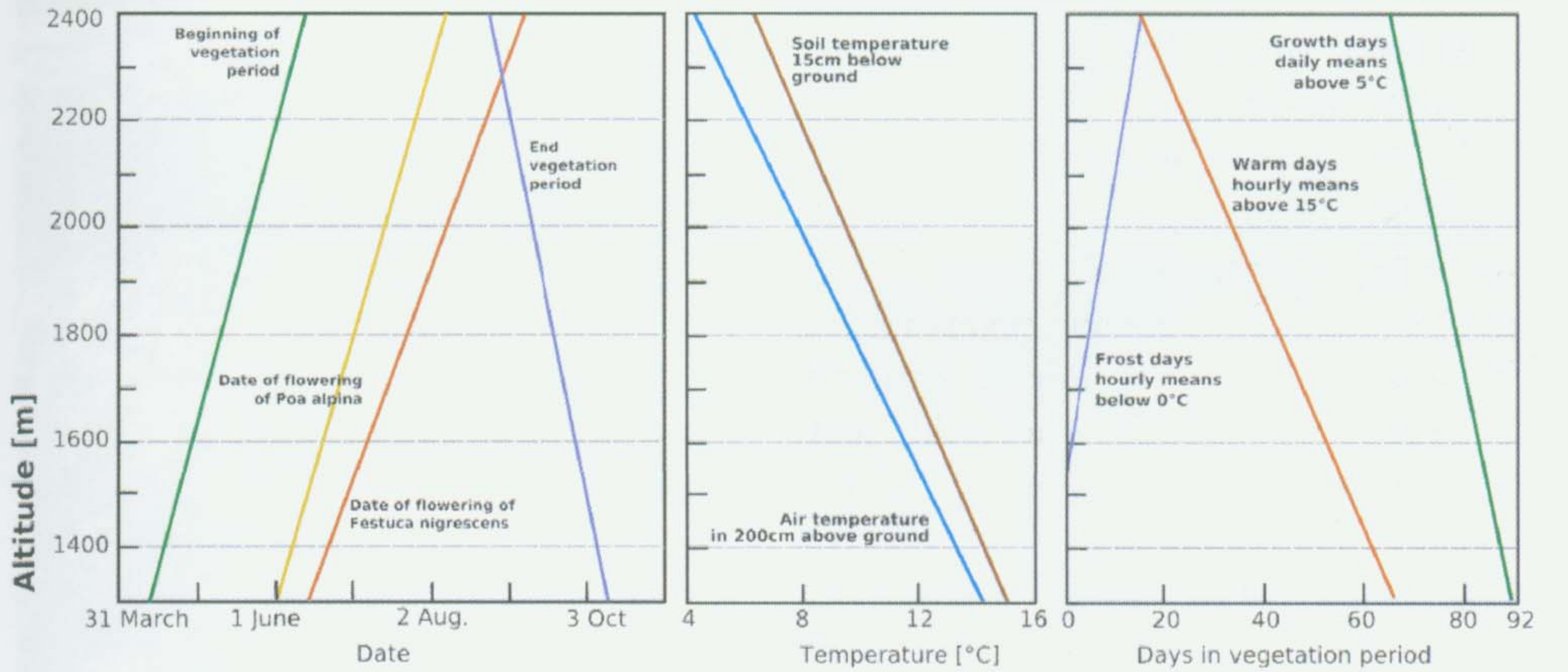


Illustration 1: Temperature changes and selected growth parameters dependent on altitude (after KRAUTZER & WITTMANN *2005)*

Reproductive phenology and seed development

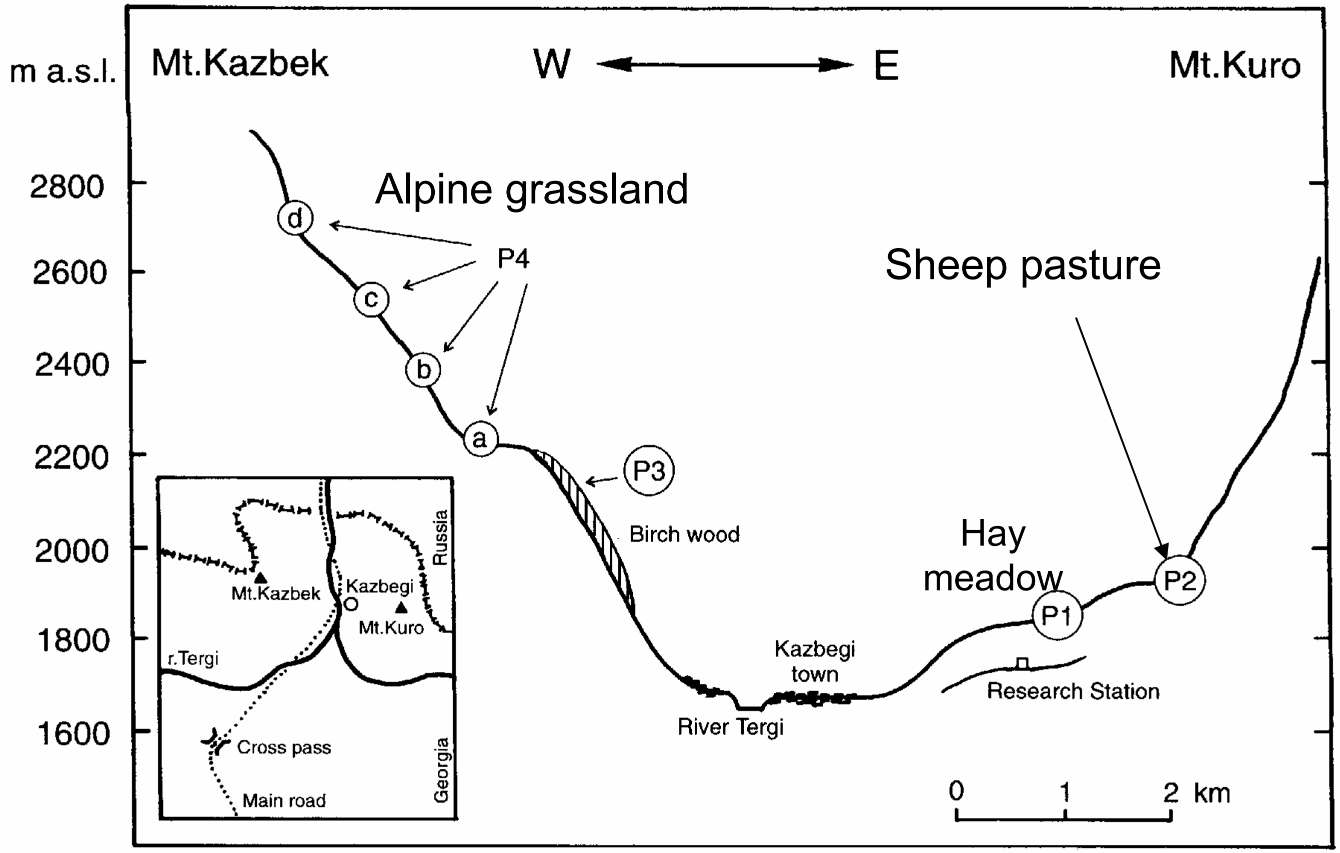


Fig. 2. Schematic profile of the study area in the Kazbegi region (Central Caucasus). P1–P4: populations of *G. caucasea*; a–d: clinal series of population P4. After KREEB et al. (1990), modified.

From M. Akhalkatsi and J. Wagner, 1996, Flora 191:161-168

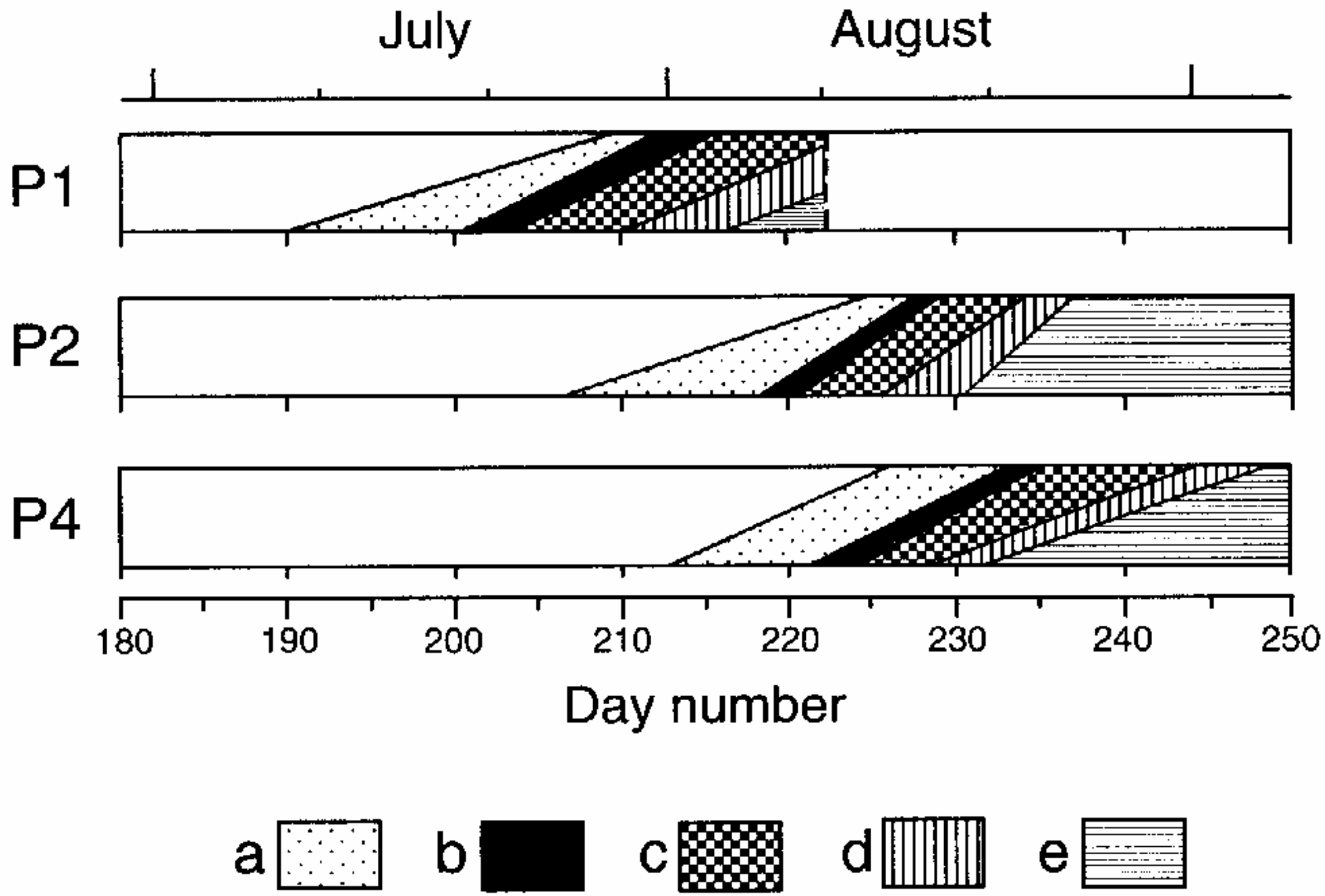


Fig. 3. Sequence of reproductive phenophases of populations P1, P2 and P4 in 1993. The phenological dates of the populations P3 and P4 are similar. Phenophases: (a) flower buds visible, (b) anthesis, (c) wilting of petals and fruit elongation, (d) fruit maturation, (e) fruit dehiscence and seed dispersal. Dotted line in P1: mowing time.

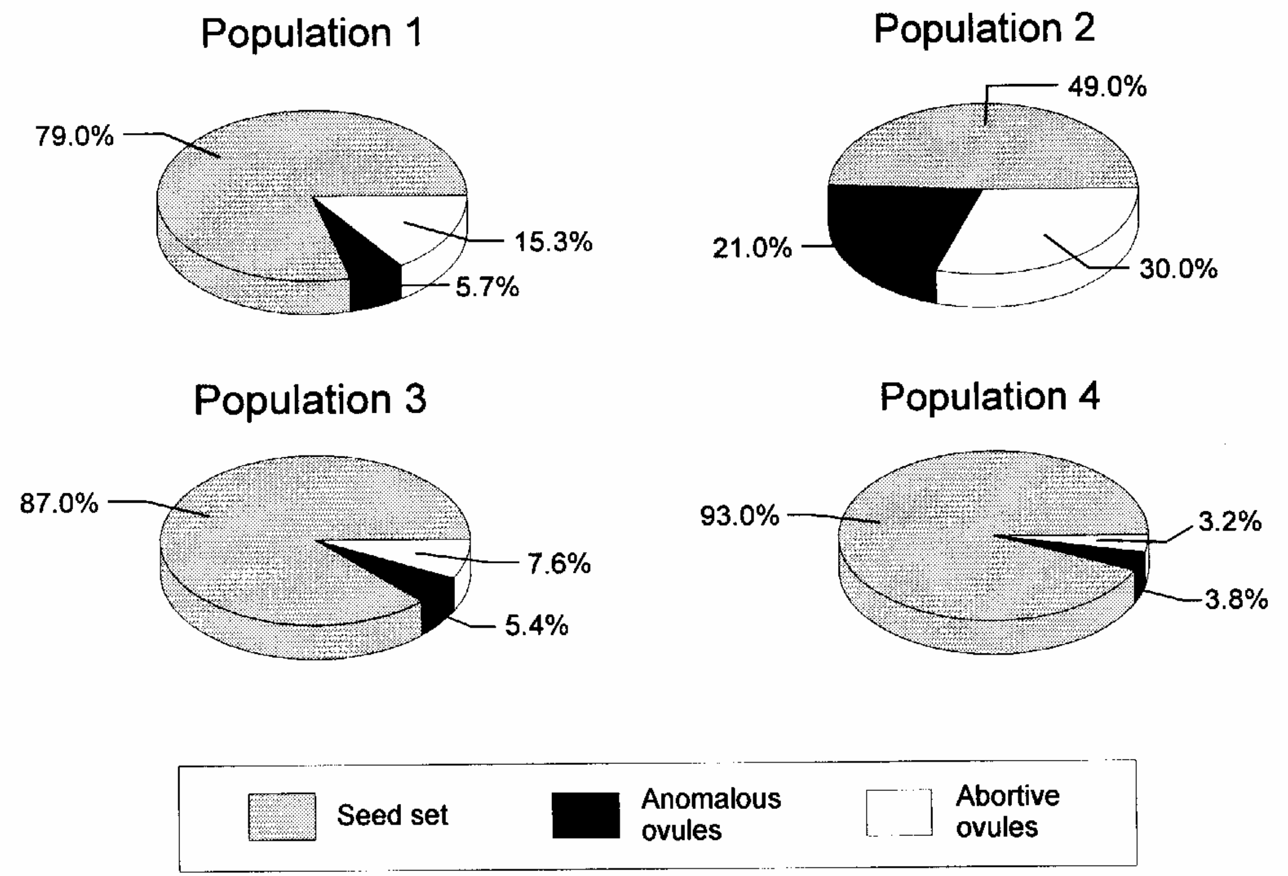
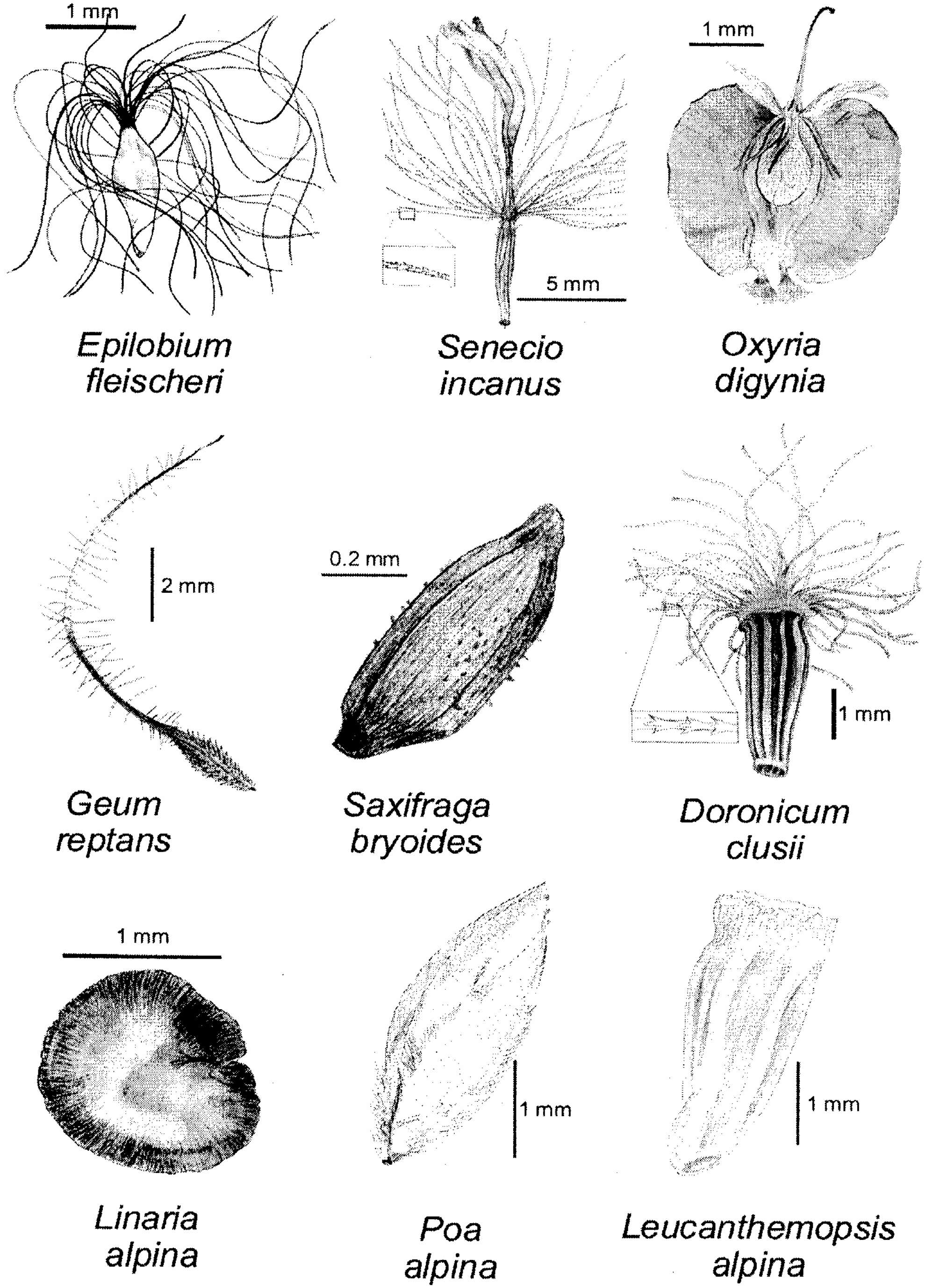


Fig. 5. Different proportions of normally developing ovules (seed set), anomalous prezygotic ovules and abortive ovules of the investigated populations of *G. caucasea*.

Diaspore traits and dispersal

- Shape
- Dispersal mode
- Dispersal date
- Longevity of seeds



App. 3. Seeds of nine alpine plant species from early successional glacier foreland vegetation. Drawings by Andreas Kaise

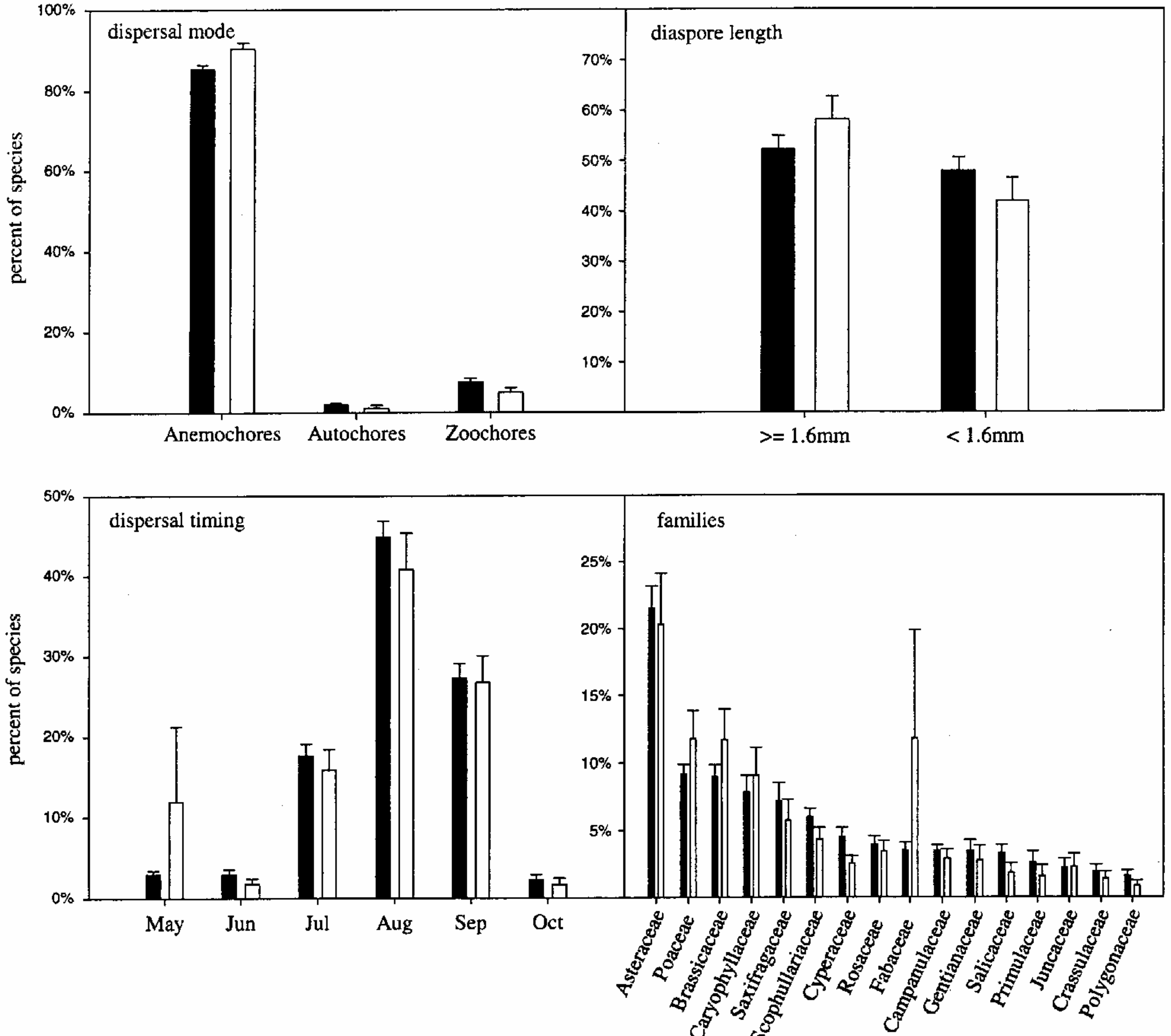
Seed shapes influence V_{term}

From:

Tackenberg O., Stöcklin,J. 2008:

Wind dispersal of alpine plant species.

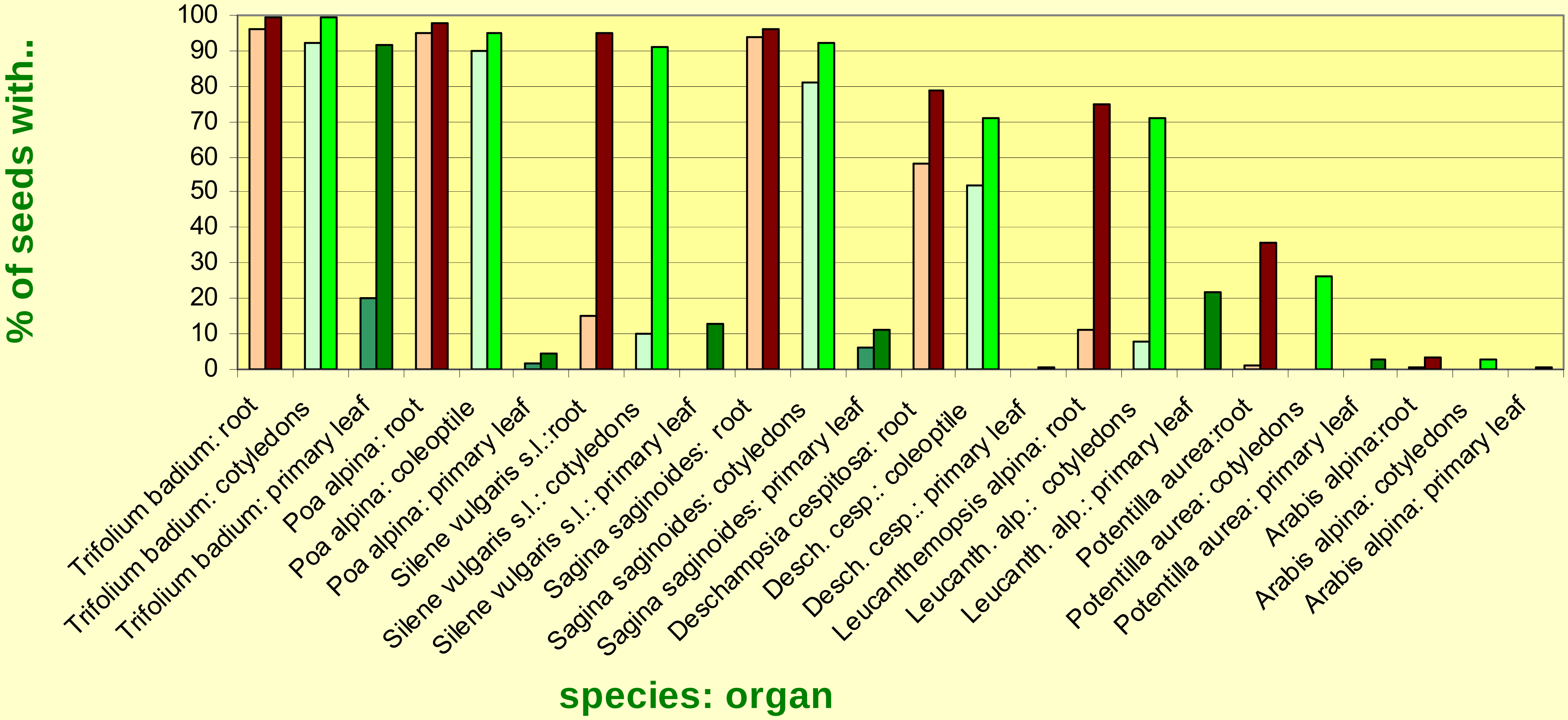
J. Veget. Sci. 19:109-118



From:

Holzinger B. et al., 2008

Germination and juvenile development of alpine plants under cool and warm summer temperature conditions (climate chamber experiment)



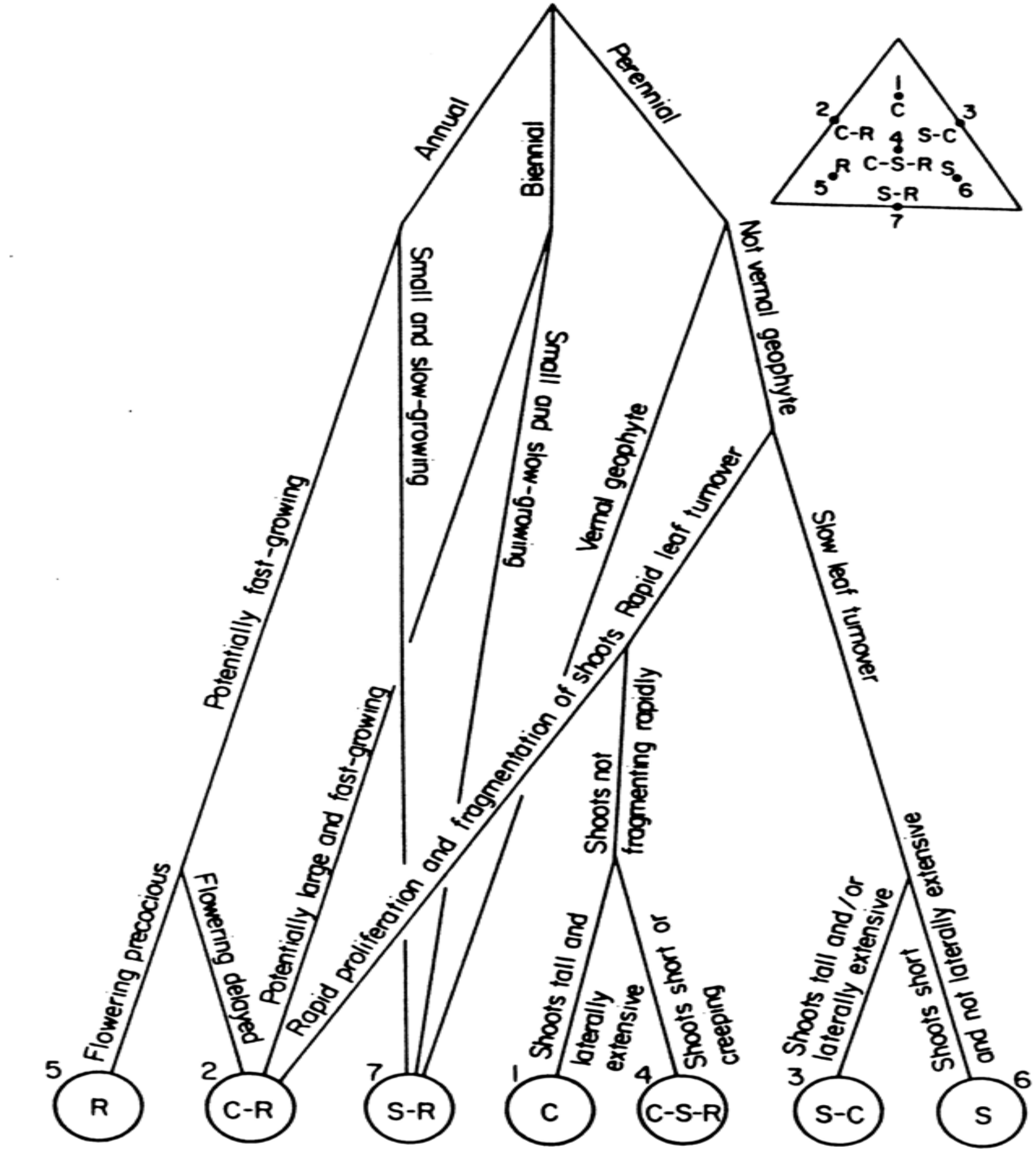


Figure 3.2 A dichotomous key to strategies in herbaceous plants, used to classify marker species in the triangular ordination. C, Competitor; S, stress-tolerator; R, ruderal; C–R, competitive–ruderal; S–R, stress-tolerant ruderal; C–S, stress-tolerant competitor; C–S–R, 'C–S–R strategist'. The location of the strategies within the triangular model (see Fig. 1.2 for axes) is shown by inset.

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

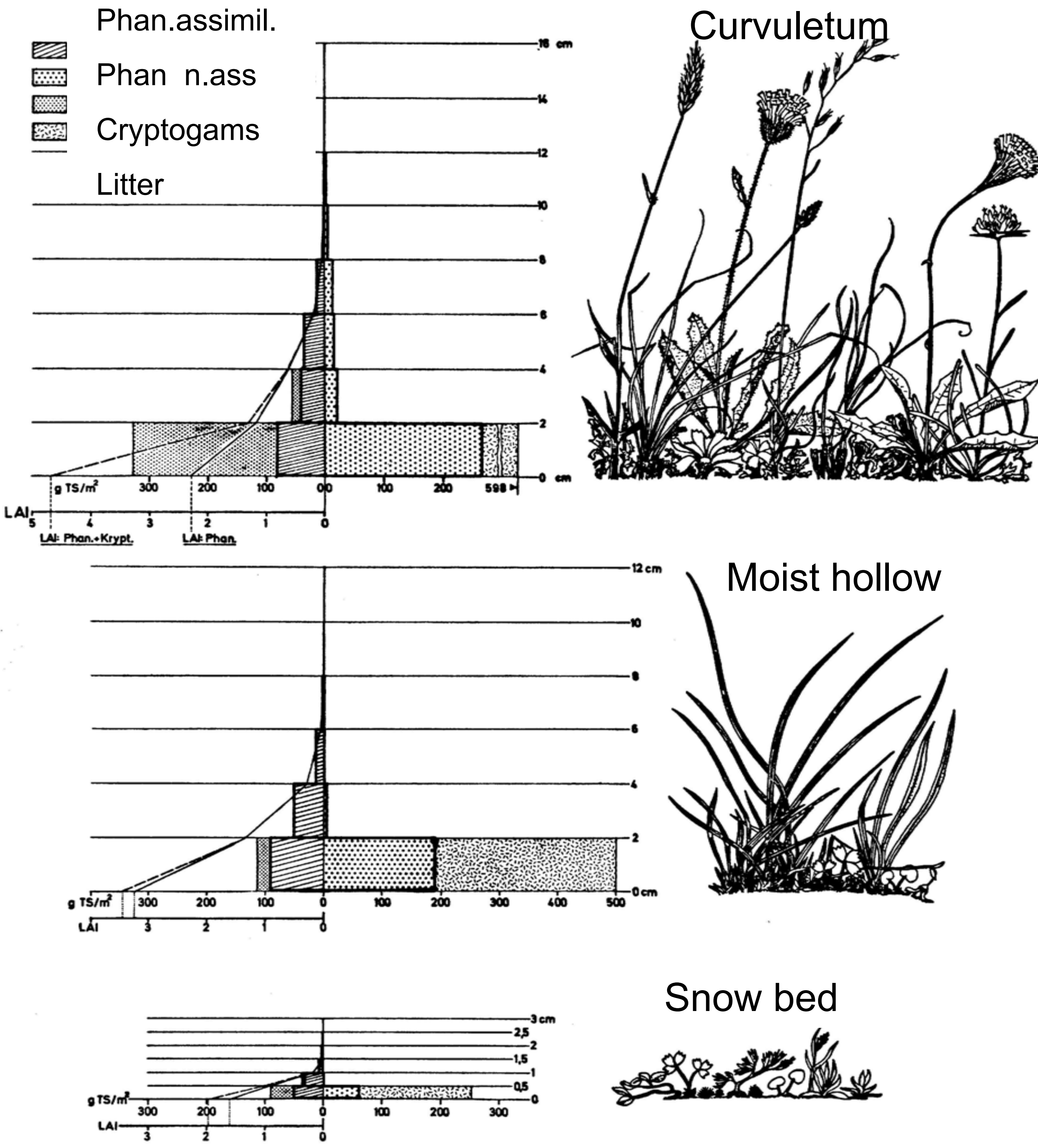
Growth forms and life spans

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

From: B. Pümpel. In: MAB-Hochgebirgsprogramm Hohe Tauern vol.1, 1977, 83-101

Curvuleturn Moist hollow Snow bed

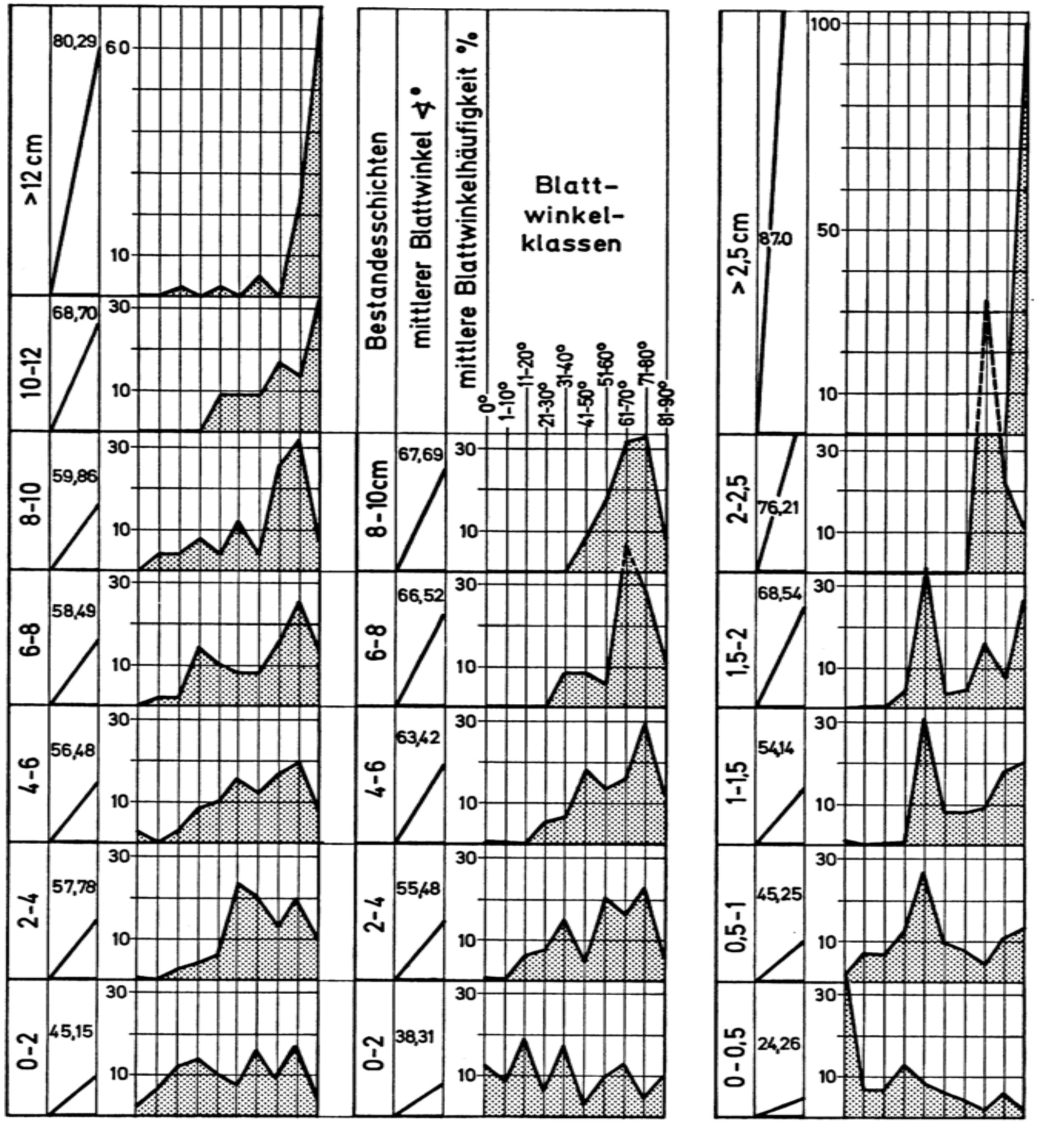


Abb. 4: Mittlere Blattwinkel der 3 Bestände in verschiedenen Bestandesschichten (jeweils linke Spalte der Darstellung) und Verteilung der gemessenen Blattwinkel auf Winkelklassen (jeweils rechte Kurve). Gesamtzahl der in jeder Schicht gemessenen Blätter = 100 %.

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

From: B. Pümpel. In: MAB-Hochgebirgsprogramm Hohe Tauern vol.1, 1977, 83-101

Short-term reactions of two alpine communities to temperature rise

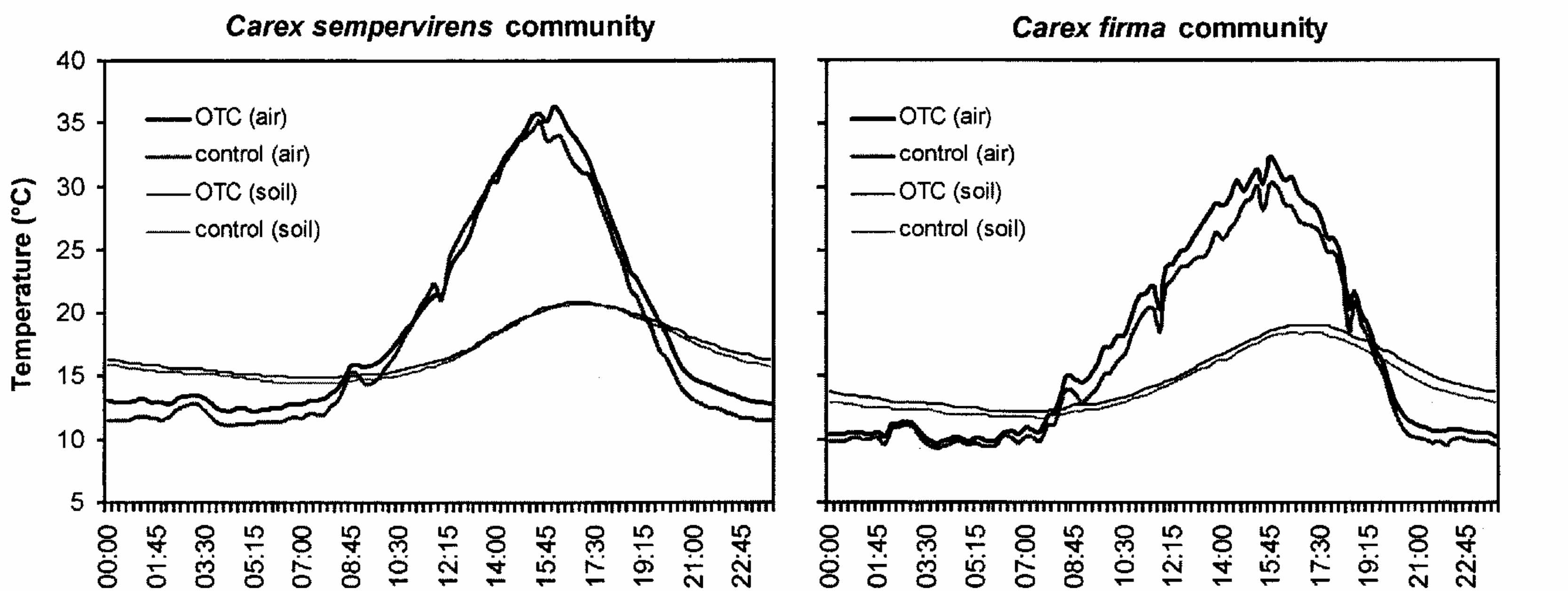
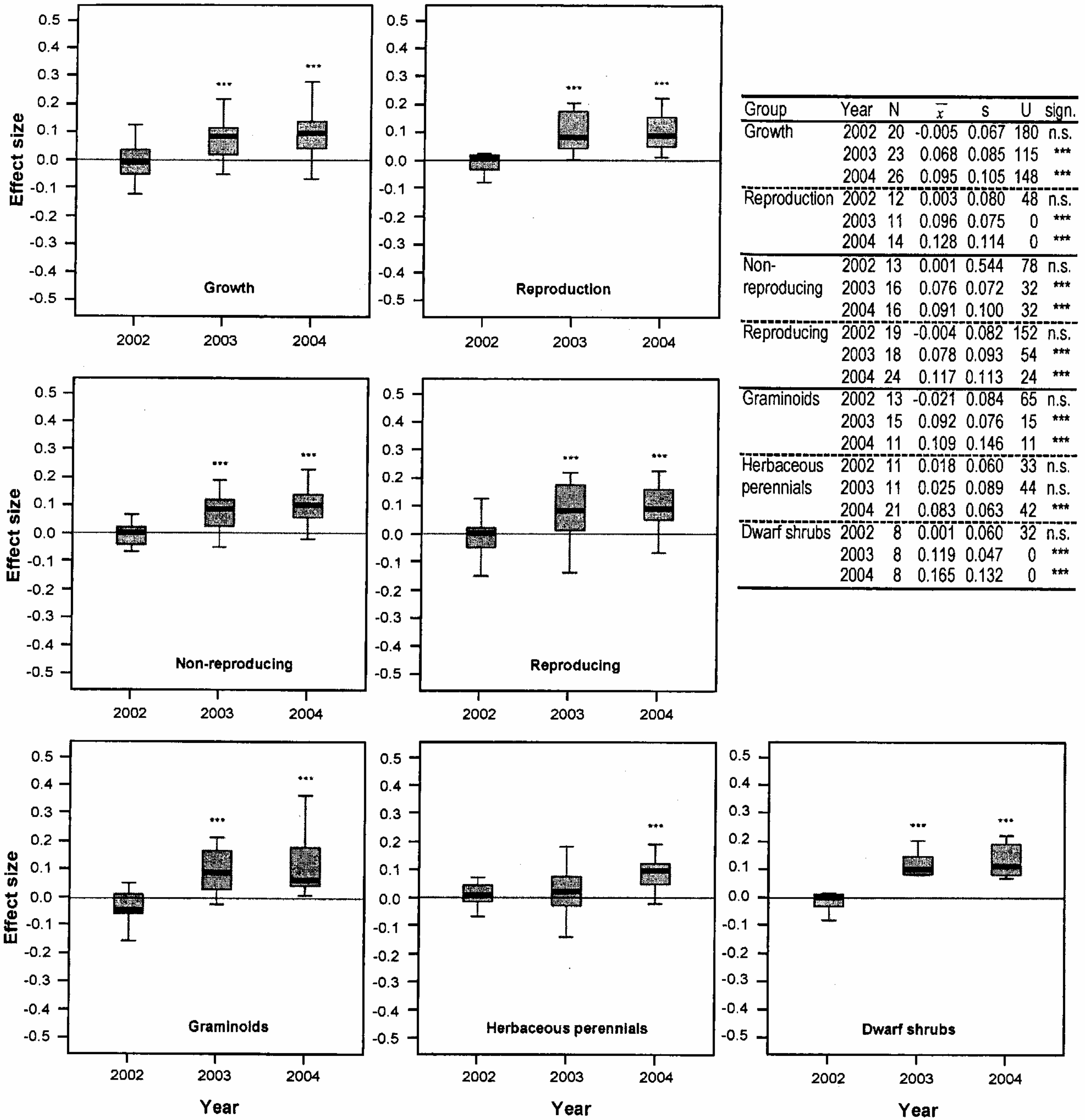


Fig. 2. Daily temperature variations in OTC- and control plots (9 August 2003), measured 2 cm above (air) and 2 cm below (soil) the soil surface. *Carex sempervirens* community: $\bar{x}_{\mathrm{OTC}}$ (air) $= 19.3$, $\bar{x}_{\mathrm{control}}$ (air) $= 18.2$, $U = 3558$, $p = 0.006$**; $\bar{x}_{\mathrm{OTC}}$ (soil) $= 17.1$, $\bar{x}_{\mathrm{control}}$ (soil) $= 16.7$, $U = 3899$, $p = 0.066$ ns. *Carex firma* community: $\bar{x}_{\mathrm{OTC}}$ (air) $= 17.1$, $\bar{x}_{\mathrm{control}}$ (air) $= 15.9$, $U = 3724$, $p = 0.022$*; $\bar{x}_{\mathrm{OTC}}$ (soil) $= 14.8$, $\bar{x}_{\mathrm{control}}$ (soil) $= 14.2$, $U = 3670$, $p = 0.015$*. *Abbreviations*: $\bar{x}$, mean, U, U-value (U-test), p, p-value (*$p < 0.05$; **$p < 0.01$; ns = 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)



Group	Year	N	$\bar{x}$	s	U	sign.
Growth	2002	20	-0.005	0.067	180	n.s.
	2003	23	0.068	0.085	115	***
	2004	26	0.095	0.105	148	***
Reproduction	2002	12	0.003	0.080	48	n.s.
	2003	11	0.096	0.075	0	***
	2004	14	0.128	0.114	0	***
Non-reproducing	2002	13	0.001	0.544	78	n.s.
	2003	16	0.076	0.072	32	***
	2004	16	0.091	0.100	32	***
Reproducing	2002	19	-0.004	0.082	152	n.s.
	2003	18	0.078	0.093	54	***
	2004	24	0.117	0.113	24	***
Graminoids	2002	13	-0.021	0.084	65	n.s.
	2003	15	0.092	0.076	15	***
	2004	11	0.109	0.146	11	***
Herbaceous perennials	2002	11	0.018	0.060	33	n.s.
	2003	11	0.025	0.089	44	n.s.
	2004	21	0.083	0.063	42	***
Dwarf shrubs	2002	8	0.001	0.060	32	n.s.
	2003	8	0.119	0.047	0	***
	2004	8	0.165	0.132	0	***

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).

Growth and reproduction of *Caricetum cuvulae* and *Caricetum firmae* plants

National Park Berchtesgaden, Germany

(Kudernatsch 2008)

All these factors contribute to the specific reaction of a plant community to environmental conditions