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# Photosynthesis and carbon metabolism of ecotypes of *Lycopersicon peruvianum* L. (Mill.) as affected by long-term chilling stress

**Wolfgang Brüggemann**

Synopsis

Three lines of *Lycopersicon peruvianum* from different altitudes were subjected to simulated bad weather periods (14 d at a constant 10°C, 100 µE $m^{-2}$ $s^{-1}$ during the photoperiod). During this time, and the subsequent recovery, photosynthesis, chlorophyll fluorescence parameters and assimilate concentrations as well as Rubisco activity were measured. The three lines responded in accordance with the prevailing climate in their habitat, i.e. the lines from the warmer climates showed the strongest impairment of photosynthesis and disturbance of carbohydrate metabolism. Both carbon fixation, measured as Rubisco activity, and electron transport reactions were negatively affected in the lines from lower altitudes, leading to severely impaired photosynthetic capacity.

*chlorophyll fluorescence, temperature stress, Lycopersicon peruvianum, photosynthesis*

## 1. Introduction

The occurrence of periods with low temperature and low light during the early growth season in mountain habitats may severely limit photosynthesis (for reviews cf. WANG 1990). Impaired photosynthesis under stress conditions can, in turn, influence species and/or ecotype distribution. The wild tomato, *Lycopersicon peruvianum* (L.) Mill., is distributed from sea level to approx. 2500 m elevation in the western Andes. In the present study, responses to simulated long-term bad weather periods were analysed in three *L. peruvianum* lines originating from different altitudes. Chlorophyll fluorescence parameters, carbohydrate pools and ribulose-1,5-bisphosphate carboxylase (Rubisco) activity were determined as a function of exposure.

Abbreviations
chl: chlorophyll, $F_m$: maximal chl-fluorescence, $F_v$: variable chl-fluorescence, $q_N$: non-photochemical quenching of chl-fluorescence, $q_P$: photochemical quenching of chl-fluorescence, Rubisco: ribulose-1,5-bisphosphate carboxylase.

## 2. Materials and methods

Three accessions of *L. peruvianum* L. (Mill.) were used in this study: LA 1373 (Asia, Prov. Lima, Peru, 20 m a.s.l.), LA 2157 (Tunel Chotano, Prov. Cajamarca, Peru, 1650 m a.s.l.), and LA 385 (San Juan, Prov. Cajamarca, Peru, 2400 m a.s.l.) (RICK 1982). Seeds (kindly provided by IVT, Wageningen, Netherlands) were germinated in TKS 1 substrate (Floragard, Oldenburg, FRG) and plants were grown in a glasshouse at 24°/18°C, 70-80% RH and approx. 150 µE $m^{-2}$ $s^{-1}$ photon flux density. Chilling treatments of 4-6 week old plants at 6 or 10 °C were performed as described (BRÜGGEMANN 1992).
Photosynthetic activity, chl fluorescence parameters and carbohydrate contents were determined as described earlier (BRÜGGEMANN 1992). Rubisco activities ($Mg^{2+}$, $HCO_3^-$-activated) were measured at room temperature according to BESFORD (1984) and corrected for 20°C using an activation energy of 66.4 kJ $mol^{-1}$ (GRAFFLAGE 1990). Only data from the 10°C treatments are shown. All parameters were also measured in experiments at 6 °C with similar results.

## 3. Results and Discussion

Photosynthetic capacity was severely affected by a mild chilling treatment in the two accessions from 20 (LA 1373) and 1650 m a.s.l. (LA 2157), while the accession originating from 2400 m a.s.l. (LA 385) appeared to be quite resistant to the long-term stress (tab. 1). The chl-fluorescence parameters (fig.1) showed that no photoinhibition had occurred during the cool treatment (cf. unchanged $F_v/F_m$ ratios). All chl-fluorescence quenching parameters were unaffected by the chilling treatment in LA 385, while both LA 1373 and LA 2157 showed impaired electron transport, as indicated by the decreasing $q_P$ parameter. In these two lines, photosynthetic dark reactions were also impaired, since $q_N$ increased during the chilling treatment. A possible reason for the $q_N$ increase in LA 1373 and LA 2157 could be (reversible) phosphate limitation of photosynthesis, since hexosephosphates accumulated from 270 to 600 nmol $g^{-1}$ FW, a consequence of the increased contents of free hexoses (fig.2). By contrast, starch contents were very little affected by chilling (data not shown).

**Tab. 1:** Rates of photosynthesis of the youngest fully expanded leaf measured at 2% $O_2$, 5% $CO_2$, 20°C and 370 µE $m^{-2}$ $s^{-1}$ as affected by two weeks of chilling treatment and one week of recovery. Activities are given in µmol $O_2$ $m^{-2}$ $s^{-1}$ ($\bar{x} \pm$ SE, n = 3-5).

| Altitude/line | control | 10°C | | recovery |
|---|---|---|---|---|
| | | 7 d | 14 d | 7 d |
| 20 m/ LA 1373 | 34.19 (4.13) | 18.76 (4.94) | 17.06 (2.42) | 30.90 (3.80) |
| 1650 m/ LA 2157 | 26.29 (2.70) | 22.78 (6.68) | 11.48 (2.59) | 27.75 (1.05) |
| 2400 m/ LA 385 | 43.02 (9.45) | 36.10 (1.28) | 35.15 (1.92) | 34.86 (4.00) |

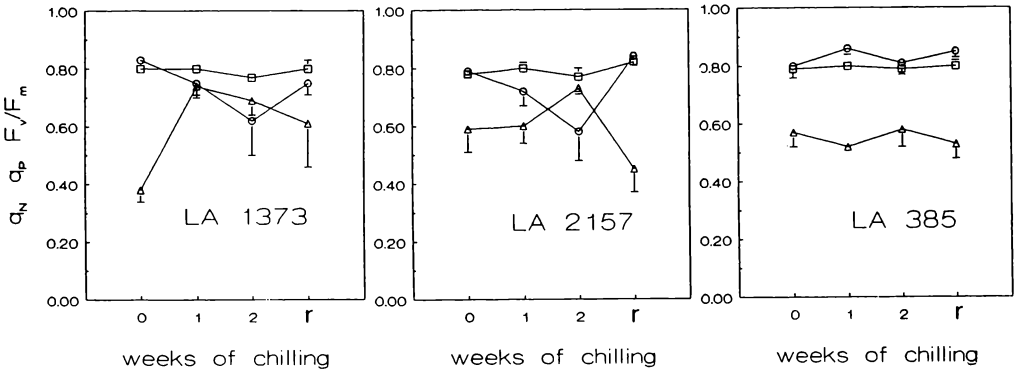


**Fig. 1:** Chlorophyll fluorescence parameters as affected by two weeks of chilling and one week of recovery (r on x-axis). Measurement conditions were as in table 1. (□ ): $F_v / F_m$, (O): $q_P$, (Δ): $q_N$ ($\bar{x} \pm$ SE, n = 3-5).

In the cultivated tomato, irreversible loss of Rubisco activity has been found to play an important role in the limitation of dark reactions during and after chilling (BRÜGGEMANN & al. 1992). In all three wild tomato lines, Rubisco was also irreversibly inactivated in the chilled leaves (tab. 2), while in new leaves expanding after the chilling stress normal activities were found. However, no limitation of photosynthetic dark reactions in the line from 2400 m was found (cf. chl fluorescence data). Possibly, in this line rubisco contents are in excess over demand under control conditions to meet a possible inactivation under chilling stress. In the Cajamarca province, average day temperatures range from ca. 13.5-16°C at 2400 m and ca. 17-20°C at 1650 m (recalculated from WALTER & LIETH 1967). In the coastal desert, average day temperatures range from 16-23°C, with the low temperatures during the growth season (Dec-Feb). The differential susceptibility of the photosynthetic capacity of the three lines to moderate chilling stress thus reflects the climatic conditions of their habitats. It is suggested that high altitude lines of *L. peruvianum* could be used in breeding programs to increase the chilling resistance of the cultivated tomato, *L. esculentum*.

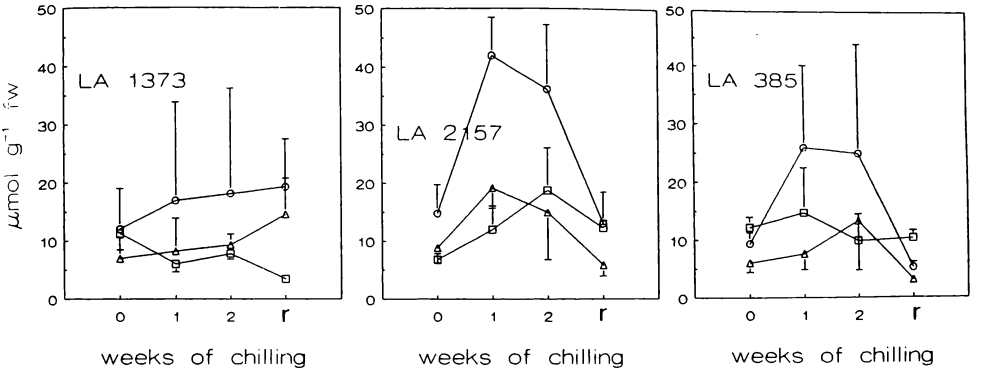


Fig. 2: Glucose (Δ), fructose (O) and sucrose (□ ) contents of leaves as affected by two weeks of chilling and one week of recovery (r on x-axis) ($\bar{x} \pm$ SE, n = 5).

Tab. 2: Leaf Rubisco activity ($Mg^{2+}$, $HCO_3^-$-activated) at 20°C as affected by two weeks of chilling and one week of recovery. Activities are given in µmol $CO_2$ $g^{-1}$ FW $min^{-1}$ ($\bar{x} \pm$ SE, n = 5).

| Altitude/line | control | 10°C | | recovery (7 d) | |
|---|---|---|---|---|---|
| | | 7 d | 14 d | old leaves | new leaves |
| 20 m/ LA 1373 | 6.93 (0.83) | 5.49 (0.63) | 4.46 (0.22) | 4.78 (1.65) | 7.40 (2.87) |
| 1650 m/ LA 2157 | 8.93 (1.08) | 4.21 (0.40) | 4.48 (1.15) | 3.98 (0.43) | 6.15 (0.67) |
| 2400 m/ LA 385 | 9.99 (1.03) | 5.36 (0.87) | 5.96 (0.84) | 5.24 (1.33) | 6.98 (0.72) |

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**Address**

Wolfgang Brüggemann
Inst. für ökologische Pflanzenphysiologie
Heinrich-Heine-Universität
Universitätsstr. 1

D-4000 Düsseldorf