Are winter hardiness and water distribution in crown tissue of sugar beet (*Beta vulgaris* L.) dependent on maximum beet diameter?

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Introduction

The cultivation of 'winter beets‘ (sowing in summer, overwintering in the field, harvest in early summer) in Germany has been discussed in recent years, since winter beets offer the potential to increase the total biomass yield due to improved utilization of the site specific growth factors radiation and water in spring. By now, it is well known that the frost tolerance of the plants is closely related to their size. While sugar beets with maximum beet diameters of 1 - 2 cm tolerate sub zero temperatures in crown tissue of about -5 °C, bigger taproots get damaged by frost. Since formation of ice crystals during freezing of plant tissue is thought to begin in the apoplast, higher frost tolerance of smaller sugar beets might be due to smaller amounts of extracellular water. The aim of this study, funded by the German Federal Ministry of Education and Research, was to investigate the influence of maximum beet diameter on winter hardiness and water distribution in crown tissue of sugar beet taproots.

Methodology

Site

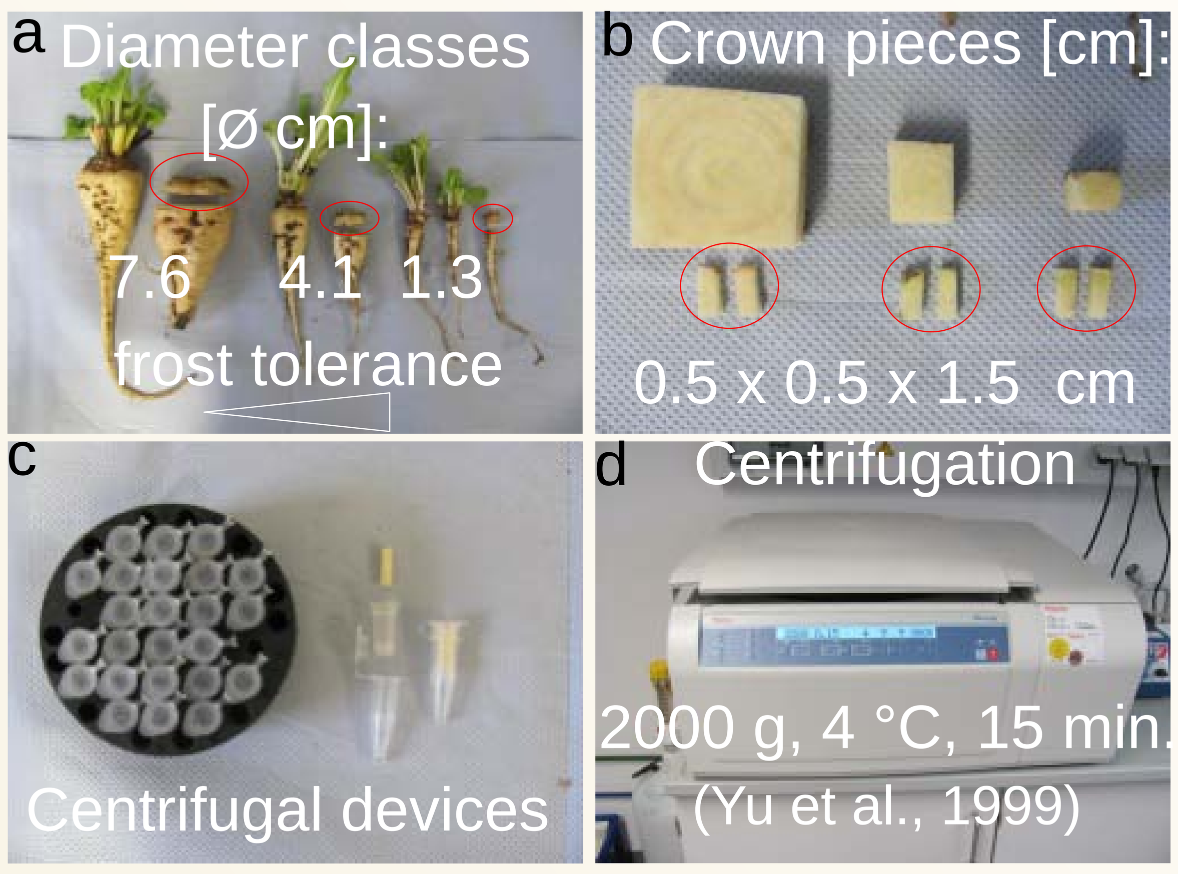
- Göttingen (51° 28'N, 9° 54'E), Lower Saxony, continental climate

Experimental factors

- Main plot: Sowing date (SD) April, June and August
- Sub plot: Plant density (PD) in 1000 plants ha^{-1}: 148, 246, 370

Measurements

- Determination of survival rate in April by counting vital, lethal & total no. of plants per row
- ‘Whole plant’ harvest of three root diameter classes, expressed as mean of max. beet diameters of beets sampled per diameter class, (a) in December 2011 before exposure to frost
- Centrifugal extraction of extracellular water (c, d) from crown pieces (b) and gravimetrical determination of total, extracellular (apoplastic) and intracellular (symplastic) water in the top 1.5 cm of the beets



- N = 12 samples per diameter class, consisting of 24 crown pieces, respectively

Results

- Survival rate decreased with increasing max. beet diameter [Fig. 1]
- Increasing max. beet diameter resulted in an increased dry matter content and a decreased content of intracellular water [Fig. 2]
- Increasing dry matter content with increasing root diameter was due to ontogenesis of sugar beet
- Small sugar beets (Ø 1.3) (highest frost tolerance) had the significantly lowest amount of extracellular water (Ø 4.1, Ø 7.6) [Fig. 2]
- While the percentage of intracellular water remained almost constant, beets of diameter class Ø 1.3 had ~35 % lower relative amounts of extracellular water compared to bigger sugar beets (Ø 4.1, 7.6) [Fig. 3]

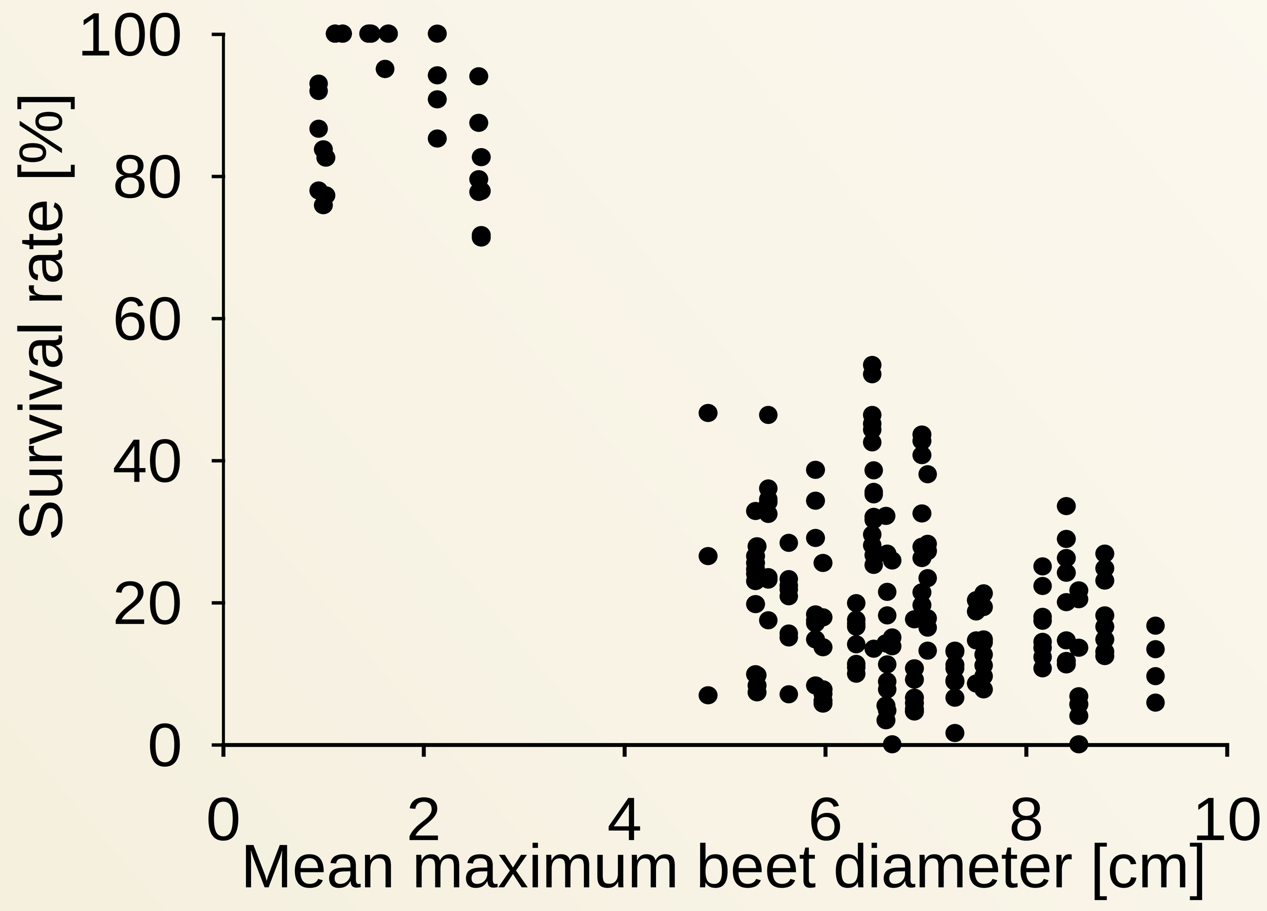


Figure 1: Relationship between mean max. beet diameter before winter and survival rate scored the following April.

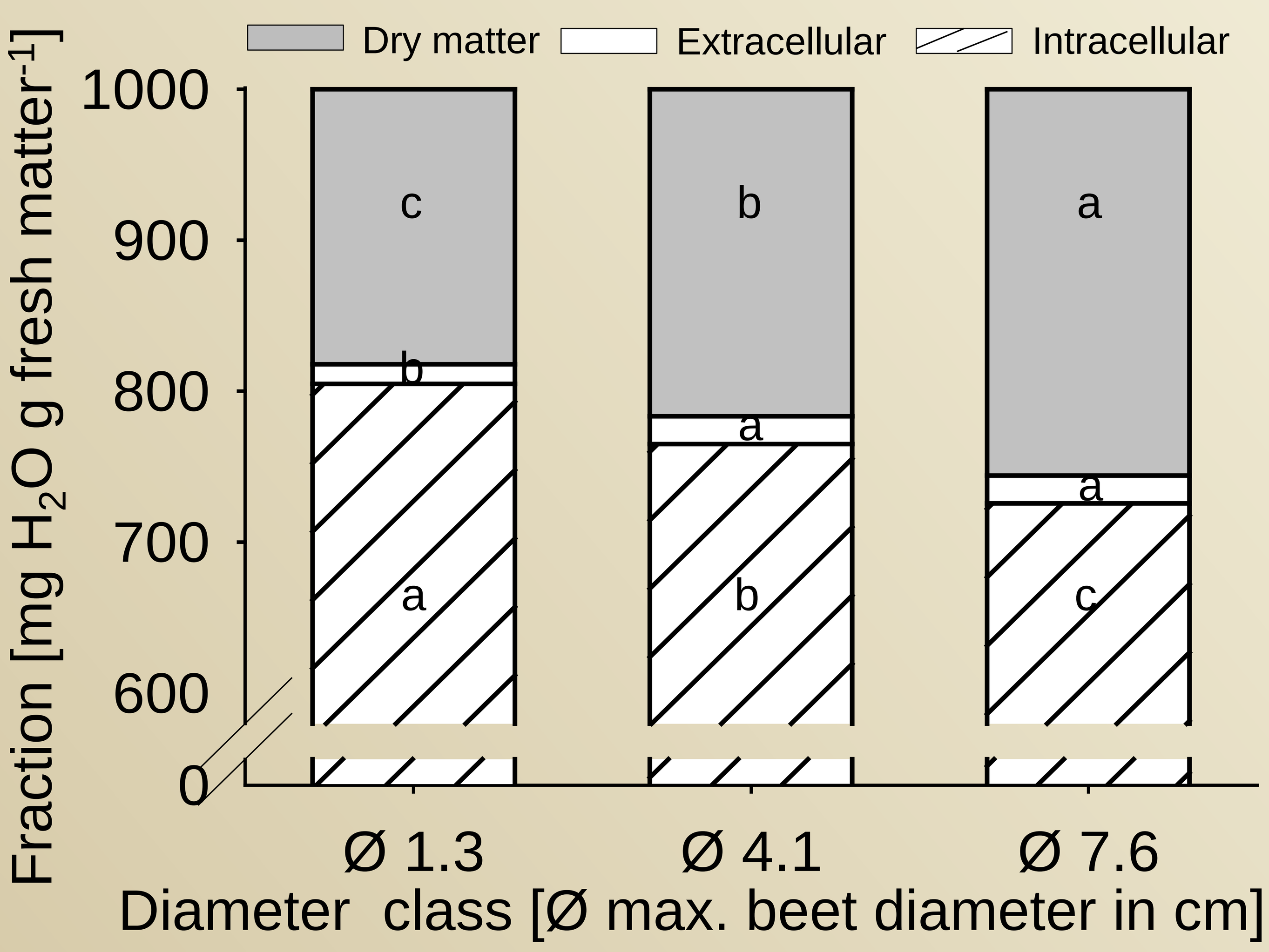


Figure 2: Distribution of water within the top 1.5 cm of sugar beet taproots as affected by maximum beet diameter. For each fraction, different letters indicate significant differences at $p < 0.05$ between diameter classes (Tukey t-Test).

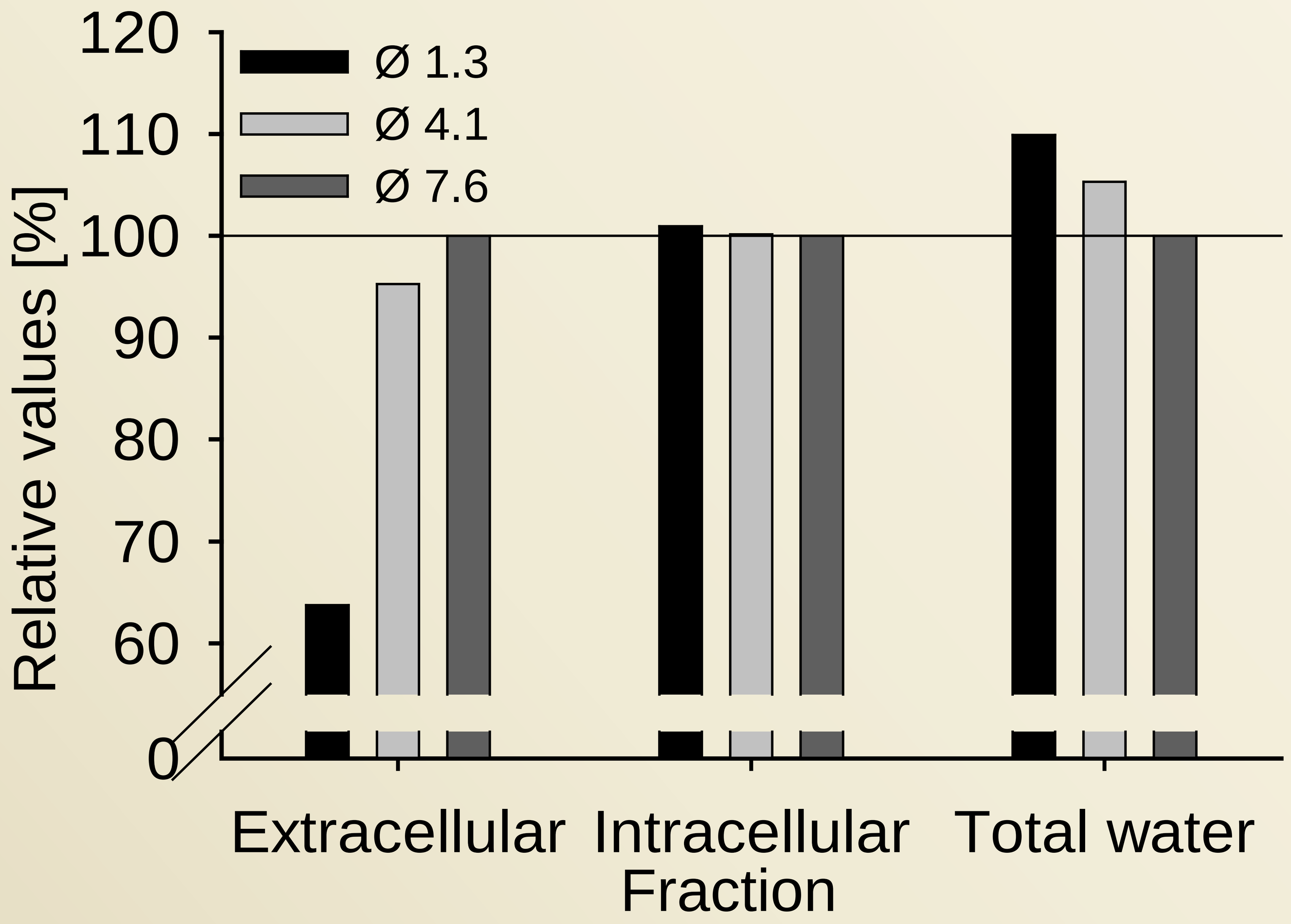


Figure 3: Relative distribution of water per fraction depending on mean maximum beet diameter. For each fraction, diameter class Ø 7.6 [cm] was 100 %.

Conclusions

The lower content of extracellular water in small sugar beet taproots (Ø 1.3) might explain the higher frost tolerance compared to plants with higher root diameters, if freezing injury in sugar beet was directly resulting from rupture of cell membranes by expanding ice crystals formed in the apoplast.