Large difference in stature between small and tall alpine forbs is not explained by different biomass and non-structural carbohydrate (NSC) allocation

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The majority of alpine plants are of small stature. Through their small size alpine plants are decoupled from the free atmospheric circulation and accumulate solar heat, thus experience less harsh climatic conditions than they would if they were taller. However, a few alpine species do not follow that "rule" and break out of the microclimatic shelter by protruding over the mean sward height with their tall stature. This exceptional "being-tall" phenomenon calls for an explanation. For this purpose, the biomass allocation of four small *versus* tall species pairs (congeneric or closely related species) has been compared in an alpine grassland at 2440 m a.s.l. in the Swiss central Alps. The concentrations of non-structural carbohydrates that is total NSC and including fructans, have been analyzed in different plant compartments at four different phenological stages during the growing season. The measured biomass allocation at "peak biomass" revealed no overall stature specific allocation pattern and an overall preferential allocation to belowground organs was observed in small as well as in the tall plant species. So, in terms of biomass formation the tall species are simply bigger. Fructans contributed substantially to the total NSC concentrations in all species and plant compartments, highlighting the importance and abundance of these carbohydrates in different alpine species. Surprisingly, also the NSC composition did not show a pronounced stature specific pattern, except for higher soluble sugar concentrations in the tall species at certain developmental stages, most likely associated with prolonged shoot growth in the tall species. Highest NSC concentrations (up to 700 mg g^{-1} d.m) were found in the belowground organs irrespective of plant size. Tall species had higher NSC pools in the rhizomes compared to other organs, whereas in small species, roots represented the dominant pool. Interestingly, the intra-specific ratios between the below- to aboveground NSC pools, were lower in the tall than the small species at peak season, pointing at a stature specific pattern.

Pulse labelling with ^{13}C enriched air at two early leaf developmental stages in three tall species indicated a very early leaf autonomy (with some differences among species), which resulted in a very rapid C translocation from leaves to belowground organs, indicating a high priority of C transfer to belowground stores. Taken together, these findings do not place tall alpine herbs in a outstanding category in terms of biomass investment and carbohydrate storage. The means by which these tall herbs reach their exceptionally tall stature seem to mainly rely on the existence of massive rhizome organs, full of NSC and partly attaining a substantial rhizome age (> 10 years) without significant, age dependent NSC losses.