Not all alpine plants are of small stature: Do exceptionally tall forbs differ in biomass and non-structural carbohydrate allocation?

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Background

The majority of alpine plants are of small stature. Through their small size alpine plants are decoupled from the free atmospheric circulation and experience less harsh climatic conditions than they would if they were taller. A few alpine species do not follow that “rule” and escape from the microclimatic shelter by protruding the mean alpine sward height with their tall stature. This exceptional “being-tall” phenomenon calls for an explanation. Do the tall forbs differ in growth and allocation of non-structural carbohydrates (NSC) from their close relatives of small stature?

Objectives

1) Assess the difference in biomass allocation between pairs of small and tall alpine forbs (congeneric or closely related species; functional growth analysis).
2) Determine the NSC allocation in different compartments of small versus tall plant pairs at different phenological stages throughout the growing season (NSC analysis).

Conclusions

1) Biomass allocation did not differ between small and tall alpine forbs.
2) Small and tall forbs are extremely rich in non-structural carbohydrates. In the tall species rhizomes were the highest NSC pool, while in the small species roots represented the dominant NSC pool.
3) The means by which the tall species reach their exceptionally tall stature mainly rely on the existence of massive rhizomes, full of NSC.

Results and Discussion

One of the four small versus tall pairs (*Gentiana acaulis* / *Gentiana punctata*. The tall *Gentiana* species was 2.4-fold taller than the small *Gentiana* species

The exceptionally tall species were 1.7 to 5.5 times taller than the (companion) small species and except for *Gnaphalium norvegicum,* all tall species protruded the average alpine sward height by several times. The functional growth analysis revealed that five out of eight species preferentially allocated the biomass to below-ground organs, but irrespective of their stature. Tall species tended to invest more into the stem fraction than small species. The NSC composition did not show a stature specific pattern, highest NSC concentrations were found in rhizomes and roots (273 ± 10 and 367 ± 14 mg g^{-1}, 39 ± 1 and 43 ± 1 % of it were fructans). Calculating the NSC pools, tall species had highest NSC pool in the rhizomes, whereas in small species roots represented the dominant NSC pool.

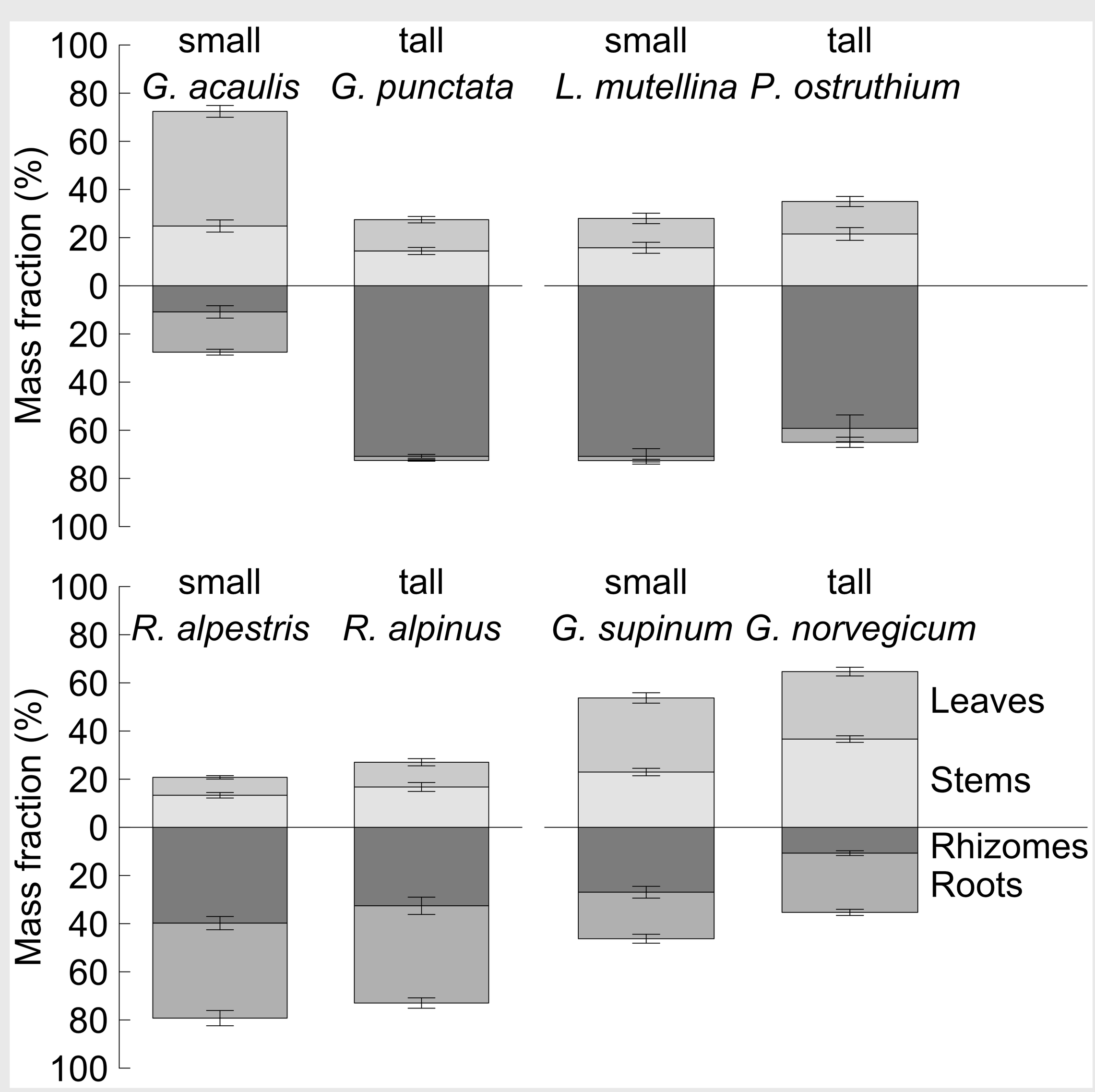

Figure 1: Mass fractions of the four small vs. tall pairs at “peak biomass“ (n = 6, mean ± s.e.)

Table 1: NSC pools in the different plant compartments of the four small vs. tall pairs at "peak biomass” (n = 6, mean ± s.e.)

Plant pair (small / tall)	Compartment	NSC pool small plant (mg per plant)	Σ	NSC pool tall plant (mg per plant)	Σ
G. acaulis / *G. punctata*	leaf	40 ± 7	77 ± 6	313 ± 83	779 ± 65
	stem	37 ± 5		466 ± 38	
	rhizome	6 ± 1	22 ± 2	2415 ± 426	2478 ± 302
	root	16 ± 2		63 ± 18	
L. mutellina / *P. ostruthium*	leaf	24 ± 7	51 ± 6	572 ± 177	1222 ± 159
	stem	27 ± 3		650 ± 139	
	rhizome	470 ± 111	483 ± 79	6372 ± 2203	7007 ± 1569
	root	12 ± 5		635 ± 266	
R. alpestris / *R. alpinus*	leaf	26 ± 7	82 ± 11	917 ± 194	2920 ± 325
	stem	56 ± 13		2003 ± 417	
	rhizome	623 ± 184	1426 ± 206	12480 ± 3490	31328 ± 3842
	root	802 ± 226		18848 ± 4164	
G. supinum / *G. norvegicum*	leaf	5 ± 1	13 ± 1	24 ± 4	63 ± 5
	stem	8 ± 1		39 ± 5	
	rhizome	10 ± 2	22 ± 2	9 ± 1	68 ± 2
	root	12 ± 1		58 ± 3	

Methods & References

Four small versus tall pairs of perennial alpine forbs were selected in an alpine grasslands at 2440 m a.s.l. (congeneric or closely related species of four different plant families): For the functional growth analysis, six individuals per species were harvested at “peak biomass”, sorted into four different compartments (leaf, stem, rhizome, root) and the corresponding mass fractions were calculated. Non-structural carbohydrates, i.e., soluble sugars (glucose, fructose, sucrose), fructan and starch in the four compartments at the four phenological stages were enzymatically digested and converted to glucose and measured spectrophotometrically.

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