Response of plant functional traits to temperature along an alpine gradient of altitude

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Abstract

Alpine landscapes are characterised by extreme topography and climate conditions with grassland occurring at sites higher than 2,000 m a.s.l. For alpine grassland ecosystems, temperature is the most limiting environmental factor for growth. We hypothesised that the expression of morphological plant functional traits reveals variation in growth rates along temperature gradients. Therefore, a transplantation experiment was conducted to search for intra-specific differences of traits along a strong altitudinal gradient in Austria. Two widespread alpine grassland species (*Trisetum flavescens* L. and *Plantago lanceolata* L.) were cultivated in flower pots under greenhouse conditions and then positioned at four altitudes between 1,092 m to 1,929 m a.s.l. Leaf length (LL), plant height (PH), leaf area (LA), specific leaf area (SLA) and surface biomass were recorded during the observation period. Results clearly indicate a strong linear relationship of plant functional traits with rising altitude, mostly driven by temperature but probably also influenced by other environmental factors such as intensity of radiation.

Keywords: alpine grassland, leaf length, leaf area, specific leaf area, plant height

Introduction

Alpine grasslands are faced with extreme climatic conditions which impact growth of plants along strong gradients of altitude and temperature. Morphological and physiological properties, i.e. functional traits of plants trigger growth processes and are, therefore, very useful to explain their climate response (Rosbakh *et al*., 2015). In our study, we focused on numerical traits of two selected, widespread plant species, which can be found in many Alpine grassland ecosystems. By means of a transplantation experiment, along an altitude gradient we investigated (1) whether phenotypical trait plasticity occurs within a short time period and (2) whether functional traits are correlated to each other (Lenzen, 2016).

Material and methods

Golden oat grass (*Trisetum flavescens cv. Gunther*) and ribwort plantain (*Plantago lanceolata*) were sown and cultivated in flower pots under greenhouse conditions at AREC Raumberg-Gumpenstein (Austria) in April 2016. In June 2016, three pots (30 cm diameter, 25 cm depth) with golden oat grass and ribwort were positioned outdoor at four different altitudes (1,092 m, 1,396 m, 1,696 m and 1,929 m a.s.l.) in Filzmoos, province of Salzburg, Austria. All sites were south-facing and plants were enclosed in metal cages to avoid damage and losses by grazing. The sites were equipped with mobile weather stations to monitor soil and air temperature. Growing degree days (GDD) defined as the sum of differences between daily air temperatures and a base temperature of 5 °C were calculated for the observation period. Leaf length and plant height were measured six times and leaf area was recorded two times during the observation period. Yield and specific leaf area were measured at the end of the experiment, after removing the pots from the sites. Analyses of variance and Pearson correlation analyses were performed using SAS version 9.3.

Results and discussion

Growing degree-days during the observation period significantly differed between the four altitudes ranging from 272 to 130 °C d from the lowest to the highest site, indicating large differences in growth conditions. SLA of golden oat grass continuously increased from 374 to 460 $cm^2 g^{-1}$ dry matter, whereas SLA of ribwort plantain was significantly lower ($P < 0.001$) and only slightly varied from 187 to 227 $cm^2 g^{-1}$ dry matter with rising altitude and decreasing temperature (Figure 1a). These findings are in contrast with other studies which show a compaction of the leaf tissue system of Alpine plants with increasing altitude (Woodward, 1979), but a few studies also confirm an exceptional increase of SLA (Wright *et al.*, 2004). The relatively short observation period probably did not allow any fundamental modification which in nature is occurring evolutionary throughout generations.

Aboveground biomass yield of ribwort was twice as much as that of golden oat grass ($P < 0.05$) with a clear decrease along rising altitude of approx. 50% between the lowest and highest site for ribwort plantain and of approx. 60% for golden oat grass (Figure 1b). With increasing altitude and unfavourable growing conditions, lower yields were probably caused by reduced metabolic activity and by an allocation of dry matter into the root system.

Average plant height and leaf length of golden oat grass decreased either significantly (PH) or slightly (LL) with rising altitude. At the first altitude level, a pronounced increase of plant height was observed during the observation period, whereas at the other sites only a moderate increase occurred. Leaf length of golden oat grass decreased both along the altitude gradient and within the growing period. In contrast, ribwort showed only minor variation in average plant height and leaf length along the altitude gradient and during the growing period.

Both plant height and leaf area were positively correlated to leaf length for golden oat grass along all altitudes whereas plant height and leaf area exhibited (non-significant) positive and negative mutual correlations, respectively. For ribwort, plant height and leaf length were strongly positively correlated along the full gradient of altitude ($P < 0.001$), whereas the relationship between plant height and leaf area as well as between leaf area and leaf length was weak (Table 1).

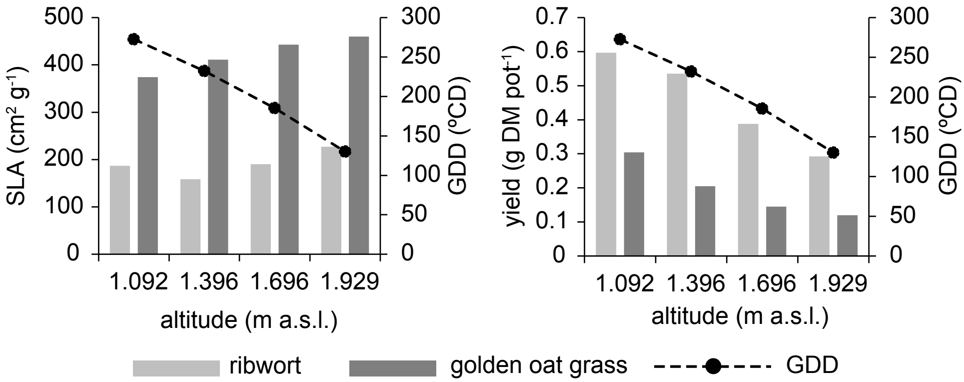

Figure 1. (a) Specific leaf area and (b) biomass yield of two species in relation to different altitudes and sum of temperature.

Table 1. Correlation matrix for functional traits of two Alpine grassland species along an altitude gradient (PH = Plant Height, LL = Leaf length, LA = leaf area).

Plant species	Altitude (m a.s.l.)	Functional traits	PH	LL
		PH	1	
	1,092	LL	0.58*	1
		LA	0.44	0.64*
Golden oat grass (*Trisetum flavescens* L.)		PH	1	
	1,396	LL	0.62*	1
		LA	-0.20	0.25
		PH	1	
	1,696	LL	0.55*	1
		LA	0.45	0.56
		PH	1	
	1,929	LL	0.32	1
		LA	-0.30	0.45
		PH	1	
	1,092	LL	0.99***	1
		LA	-0.31	-0.29
Ribwort (*Plantago lanceolata* L.)		PH	1	
	1,396	LL	0.99***	1
		LA	0.03	0.03
		PH	1	
	1,696	LL	0.99***	1
		LA	-0.35	-0.30
		PH	1	
	1,929	LL	0.98***	1
		LA	-0.30	-0.29

Conclusion

As hypothesised, functional traits of two selected Alpine plant species were significantly affected by a strong gradient of altitude. Genetically homogenous plants are able to adapt quickly to different environmental conditions indicating a high potential of phenotypic plasticity. Our findings are of increasing relevance in the context of climate change, which may alter metabolism, growth rates and phenology of individual species differently, influence grazing behaviour of ruminants and also pose challenges for farmers and agronomists with respect to adaptation of management.

References

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