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Is growth of Swiss stone pine at the alpine treeline impaired or enhanced by competition with N₂-fixing green alder?

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Green alder (*Alnus alnobetula* (Ehrh.) K. Koch = *Alnus viridis* (Chaix) DC) is a nitrogen-fixing pioneer species that is widely distributed at high altitude and latitude in the northern hemisphere. Due to changes in land management green alder is currently the most expanding shrub in the European Alps. It forms dense, tall thickets that are thought to impair establishment and growth of trees. The main focus of this study therefore was (i) to compare annual increments of Swiss stone pine (*Pinus cembra* L.), which is the dominant tree species at high elevation in the Central Eastern Alps, with that of green alder, and (ii) to determine radial growth of Swiss stone pine in competition and in absence of competition with green alder. The study area is situated within the treeline ecotone stretching from c. 1950 up to 2200 m in the Central Tyrolean Alps (Mt. Patscherkofel: 47.21 N, 11.46 E; Kühtai: 47.22 N, 11.04 E). A comparison of radial growth between similar aged stems (c. 20 yrs) revealed that annual increments of Swiss stone pine ($2311 \pm 628 \mu\text{m}$) were more than four-times larger than those of green alder ($519 \pm 92 \mu\text{m}$). This finding can be explained by different carbon allocation strategies, i.e., favouring vertical stem growth in single stemmed Swiss stone pine over preference of horizontal spreading in multi-stemmed green alder. This interpretation is supported by aerial photographs, which show that green alder stands are spreading vigorously within the treeline ecotone on Mt. Patscherkofel, amounting to c. $450 \text{ m}^2 \text{ ha}^{-1} \text{ decade}^{-1}$. Radial growth measurements of Swiss stone pine occurring inside and outside green alder thickets (canopy height 2–3 m) revealed that Swiss stone pine individuals with a comparable height to green alder (tree height: $2.9 \pm 0.8 \text{ m}$) showed significantly lower growth inside green alder stands than outside, while Swiss stone pine trees taller than green alder thickets (tree height: $6.1 \pm 1.6 \text{ m}$) grew better inside than outside green alder thickets. We explain these findings by source limitation of Swiss stone pine growth at low tree height, whereas with increasing tree height carbon assimilation is no longer a limiting factor and the higher N₂ availability within green alder thickets can be exploited for stem growth. We conclude from this study that due to its horizontal competition strategy and dense cover of its foliage green alder is able to strongly impede the establishment and growth of co-occurring late-successional Swiss stone pine. Hence, spreading of green alder due to land abandonment and decrease in grazing pressure causes a delay in the development of closed forest stands, and also hampers climate warming induced advance of the alpine treeline.

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