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Comment on bg-2021-99

Anonymous Referee #1

Referee comment on "The application of dendrometers to alpine dwarf shrubs – a case study to investigate stem growth responses to environmental conditions" by Svenja Dobbert et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-99-RC1, 2021

Due to considerable methodological deficiencies and a lack of physiological understanding of plant growth limitation in the alpine zone, I cannot recommend publication of this manuscript.

General comments:

In this paper authors analysed the influence of environmental factors on radial growth and intra-annual growth patterns of the prostrate dwarf shrub *Empetrum nigrum* ssp. *hermaphroditum*, which is widespread in arctic and alpine ecosystems. Elevational gradients spanning 500 m were selected above treeline in a humid and continental climate region in central Norway. To determine key dates of intra-annual growth dendrometers were mounted on one major stem per plant (two regions x six samples x two region, i.e., one sample per elevation result in a total of 12 dendrometer records during four successive years). Regression and correlation analyses were applied to calculate the influence of microclimate on growth parameters. Authors found that soil moisture, solar radiation and winter conditions are the main drivers of radial stem growth of *Empetrum nigrum* ssp. *hermaphroditum.* Results of this study are unexpected, as it is generally assumed that in the temperate climatic zone growth processes at and above treeline are primarily limited by temperature during the growing season.

Although authors present a unique data set of dendrometer records of an alpine shrub species together with site specific environmental data during four years, I have several major concerns regarding study design and analysis: (i) I suppose that due to selection of only one individuum per elevation, dendrometer records gathered along the elevational gradient were averaged in both regions, i.e., dendrometer data sampled along a temperature gradient of 3°C (500 m elevational gradient x 0.6 °C temperature lapse rate per 100 m elevation) were averaged to obtain a mean dendrometer series per region (n=6 per region), which were correlated with mean values of environmental variables. This averaging procedure, however, precludes a detailed and meaningful analysis of the influence of temperature on shrub growth at and above treeline (cf. comments to p. 9,

line 205 and p. 10, Fig. 2). (ii) Diameter dendrometers were mounted over dead outer bark, which is a highly hygroscopic tissue. The possible influence of daily/seasonal changes in air humidity on stem diameter variations were not taken into consideration (cf. comments to p. 5, line 135). (iii) There are numerous inconsistencies in data interpretation which need to be clarified to justify publication.

Specific comments and suggestions:

p. 1, line 15: Elevational effects on stem growth were not analysed in this study, because dendrometer records were averaged. This procedure precludes the analysis of effects of decreasing temperature with elevation on growth.

p. 1, line 18: There are inconsistencies here: According to Table 3, onset of growth did not start before DOY 173. Furthermore, mean shoot and root temperature were below 0°C in March-April 2015-2017 and < 5°C in May 2018. How can it be possible that these correlations have come about? Please clarify.

p. 1, line 19: Photosynthetic activity during winter at daily mean temperatures < -10 °C is highly speculative and rather implausible.

p. 3, line 75: "caused by induced water" – unclear meaning, please reword.

p. 3, line 78: "inter-annual" or "intra-annual" – please check.

p. 3, line 84: Dendrometers used in this study record stem diameter variations, whereas point dendrometers record radial stem variations. Please correct.

p. 3, line 88: Please explain meaning of "mechanistic adaptation".

p. 4, line108: Please indicate that sites at 900 and 1000 m asl are (natural?) treeline sites. Has the elevation of the tree line been influenced by humans? Are study sites selected along the elevational gradient influenced e.g., by grazing? Furthermore, it is quite important to indicate slope and exposure of all study sites, as well as plant structure (height) of selected shrubs, because all these factors affect temperature that the plants experience (cf. Körner 2021).

p. 4, line 114: Please indicate mean height of shrub-canopy along elevational gradients.

p. 5, line 128: DRO-dendrometers measure stem diameter variations and therefore are different from point dendrometers. To avoid misunderstanding, please correct.

p. 5, line 135: Please consider that the "daily mean approach" yields time series of daily stem diameter variations, which include both water- and growth-induced diameter changes. Several authors found that bark is a highly hygroscopic tissue (e.g., Ilek et al. 2016, Gall et al. 2002). Therefore, stem diameter changes recorded by dendrometers mounted on dead outer bark as in this study may be affected by evaporation and absorption of water from the bark tissue. Dead outer bark should be (completely) removed to reduce hygroscopic shrinkage and swelling of dead tissues on dendrometer records. To be able to unequivocally relate stem diameter fluctuations to environmental parameters and accurately determine stem water deficit, hygroscopic processes must be taken into account even when dendrometers were mounted over even thin dead outer bark layers (cf. Oberhuber et al. 2020). Therefore, authors need to demonstrate the lack of influence of changes in diurnal and seasonal air humidity on changes in stem diameter. Because hygroscopic effects could partly explain unexpected climate-growth relationships found in this study (i.e., influence of winter freezing conditions, soil moisture availability, solar radiation) I suggest adding records of daily (seasonal) changes of relative air humidity within study regions.

p. 5, line 144f: The phrases "…hydrological processes", and "reversible shrinking and swelling associated with the stem water deficit" are unclear, please reword.

p. 5, line 146: I suggest adding "the final growth curve", which was used to determine relationships between stem growth and environmental variables.

p. 6, line 169-174: Sentence starting with "Buchwal et al. (2013)…." and the following sentence belong to discussion section.

p. 6, line 174: Please explain "non-growing seasons" or reword.

p. 6, lines 184ff: Please add manufacturer of soil moisture and radiation sensors. Furthermore, was the radiation sensor mounted on an open site or below "canopy".

p. 7, Figure 1: I suggest showing not only daily mean values of shoot and root zone temperatures but also daily mean maxima and minimum temperatures.

p. 8, Legend of Table 1: “inter-stem variability” or “site variability”? Please check.

p. 9, line 205: Has the abbreviation GDD10 been explained before?

p. 9, lines 202-211: This paragraph belongs to results section.

p. 9, line 205: Do authors have any explanation why temperatures vary only slightly between sites? Along an elevational gradient spanning 500 m (900 to 1400 m asl and 1000 to 1500 m asl) and taking a temperature lapse rate of 0.6 °C per 100 m elevation into account, a temperature difference of 3 °C between the lowest and highest study site is to be expected. Furthermore, also soil moisture shows low variability although selected study regions belong to the humid and continental climate zone. Please discuss these findings.

p. 9, lines 220ff: This sentence belongs to discussion section.

p. 10, Figure 2: It is quite surprising that mean monthly shoot and root zone temperatures reach similar maxima (around 8-10 °C) during the supposed main growing season (June-September). This is most likely an effect of averaging temperature records along the elevational gradient or selection of sites showing different slope and/or exposure. The extended elevational transect would be an ideal study design to investigate the influence of shoot and root zone temperatures on growth of this dwarf shrub. Unfortunately, limited sample size (one dendrometer record per elevation) precludes any analysis in this regard.

p. 11, line 245: “with the daily growth for each season” – Stem growth does not occur during all seasons (cf. Fig. 3)? Please clarify meaning of “daily growth” in this respect.

p. 11, Table 2: Please explain inverse relationship between growth cessation and total annual growth: the later growth stops during the year, the lower the annual increment? Also add explanation of abbreviation “Part” in legend.

p. 14, Figure 3: Determination of stem water deficit is most likely influenced by bark hygroscopicity (see comments to p. 5, line 135). I suggest removing Figure 3d. Furthermore, is “stem diameter variability” or are “stem radial variations” depicted in Figure 3b. In Table 4 values of “stem radial growth” are shown. Please clarify and be consistent in using “stem diameter variations” or “stem radial variations” throughout the text.

p. 15, Table 4: Please check value of “stem radial growth” in 2017, which amounts to “14185”.

p. 15, line 285f, Figure 4: All 25 environmental parameters explained total annual growth? How is this to be explained? Not all relationships are statistically significant.

p. 16, line 291f: “main growing phase during spring” – see comment to p. 1, line 18 (no spring growth according to Table 3). Please clarify.

p. 16, line 296: Is “R” Pearson correlation coefficient? If yes, change to “*r*” throughout the manuscript.

p. 16, line 298: Influence of soil moisture availability on “growth processes” throughout “all four seasons” is highly speculative because (i) leaf water potentials were not determined, (ii) mean values of soil moisture given in Fig. 1 are not indicating drought stress during the growing season in both study regions, and (iii) most alpine plants have a small fraction of deep roots reaching up to 1 m depth. Furthermore, which “growth processes” were influenced throughout the year?

p. 16, line 300: Sentence starting with “This result…” belongs to discussion section.

p. 18, Figure 5: It is highly surprising that Pearson correlation coefficients between “radial stem diameter and micro-environmental data” are almost all highly significant throughout the year including lag phases extending from three days to one year. Did authors check for normal distribution of data? Furthermore, Deslauriers et al. (2007) suggested including only the main period of growth to assess relationships between environmental variables and dendrometer data. Therefore, to determine climate–growth relationships, only the most linear growth phase should be considered, i.e. correlations should be calculated for e.g. the period ±14 days around the inflection point of the Gompertz model. Furthermore, to determine environmental influences on growth, radial stem increments extracted from dendrometer records according to e.g. Zweifel (2016) should be used in the correlation analysis rather than “daily values of stem variability” (which include reversible shrinking and swelling of the bark). Figure 5a: “Correlation with mean values”: which mean values, annual means? Please add and also indicate meaning of significance symbols in legend.

p. 20ff: The discussion sections needs to be substantially revised based on comments given above. Extended speculative data interpretations should be avoided.

p. 20, line 322: Sub-heading is not appropriate – please reword.

p. 20, lines 324 and 330: Topographical effects on growth of *Empetrum* were not analysed in this study, because all sites were located on exposed ridge positions.

p. 20, line 335: "intra-plant growth variability" – in Fig. A1 and A3 inter-plant variability is shown, please check wording.

p. 20, line 329: "very similar seasonal growth patterns" – In Fig. A4 I see large differences in stem diameter changes between regions in 2015 and 2018. Please clarify.

p. 22, line 386f: "negative correlation between stem diameter variation and number of snow-free days" –"stem diameter variation" is different from stem growth; please clarify.

p. 22, line 391: "to prepare for the following winter" – Why preparing for winter period? Please explain in more detail.

p. 22, line 408f: Regarding importance of soil moisture availability for growth, see comment to p. 16, line 298.

p. 22, line 413f: Onset of budbreak and plant growth in spring in the alpine zone is generally related to increase in temperature and photoperiod. A relationship between photosynthetic activity and growth onset is mere speculation and not substantiated by any previous study in the scientific literature (cf. Körner 2021).

p. 23, lines 418-440: Speculative discussion should be condensed. Regarding frost induced stem shrinkage in the literature please see and cite Zweifel and Häsler (2000) and King et al. (2013). Furthermore, regarding importance of carbon assimilation for growth onset and soil moisture availability for growth cessation, it is well known that in alpine plants no critical depletion of carbohydrates occurs in the seasonal cycle, and in temperate climate zones alpine plants initiate winter bud formation tightly coupled to the photoperiod, respectively (cf. Körner 2021).

p. 24, line 459: "photosynthetic activity throughout the year" – It is highly implausible for photosynthesis to occur throughout the year, i.e. at mean temperatures below -10°C (Table 1, Fig. 1).

p. 24, lines 475ff: Climate warming has caused an increase in growth of shrubs in arctic and alpine ecosystems. I would assume that a further rise in temperature would primarily promote the spread of shrubs (and trees) in these temperature limited ecosystems rather

than impair it.

References cited:

Deslauriers A, Rossi S, Anfodillo T (2007) Dendrometer and intraannual tree growth: what kind of information can be inferred? Dendrochronologia 25, 113–124.

Gall, R, Landolt, W, Schleppi, P, Michellod, V, Bucher, JB, 2002. Water content and bark thickness of Norway spruce (Picea abies) stems: phloem water capacitance and xylem sap flow. Tree Physiol 22, 613–623.

Ilek, A, Kucza, J, Morkisz, K, 2016. Hygroscopicity of the bark of selected forest tree species. iForest 10, 220–226.

King G, P Fonti, D Nievergelt, U Büntgen, D Frank (2013) Climatic drivers of hourly to yearly tree radius variations along a 6 °C natural warming gradient. Agr For Meteorol 168:36-46

Körner C (2021) Alpine plant life. Functional ecology of high mountain ecosystems. Springer.

Oberhuber W, M Sehrt, F Kitz, 2020, Hygroscopic properties of thin dead outer bark layers strongly influence stem diameter variations on short and long time scales in Scots pine (Pinus sylvestris L.). Agr For Meteorol 290, 108026

Zweifel R (2016) Radial stem variations - a source of tree physiological information not fully exploited yet. Plant Cell Environ 775, 231–232.

Zweifel R, R Häsler (2000) Frost-induced reversible shrinkage of bark of mature subalpine conifers. Agr For Meteorol 102:213-222.