ANNUAL RING WIDTHS IN THE ARCTIC-ALPINE DWARF-SHRUB SPECIES *BETULA NANA* - DATASET FROM LONG-TERM ALPINE ECOSYSTEM RESEARCH IN CENTRAL NORWAY (LTAER-NO)

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With 3 figures and 1 dataset supplement
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Summary: Here we present a Data Paper with microscopically measured data on ring widths of the arctic-alpine dwarf shrub species *Betula nana* L. from Central Norway. We intend to continuously update the dataset in the future with further ring width measurements of this widespread shrub species.

Keywords: Dendrochronology, wood anatomy, annual growth patterns

1 Background, aims, and objectives

In the face of ongoing climate change, the still open question of when, how and why plants grow is a highly topical issue in alpine research. Therefore, the focus of current studies across biomes that aim to assess seasonal radial growth of woody alpine plants is on using high-resolution dendrometer measurements to better understand plant growth and predict species response to future changes (Dobbert et al. 2021a, 2021b, 2022b, 2022c, Albrecht et al. 2022, 2023a, 2024a, 2024b). At the same time, there are numerous studies addressing the same or related questions by applying classical dendroecological techniques based on wood anatomy of alpine shrubs (Francon et al. 2017, 2020a, 2020b, 2021, 2023, Piccinelli et al. 2023, Pereira et al. 2023). Moreover, studies focusing on alpine soil temperature and near-surface air temperature variability enhanced our knowledge on potential responses of alpine ecosystems to global climatic change (Pape et al 2009, Wundram et al. 2010), as did studies on spatial patterns of alpine phytomass, primary productivity and associated caloric resources (Pape & Löffler 2016, 2017). In this context, arctic and alpine ecosystems of the tundra biome are of particular interest, as they are strongly affected by an intense warming trend (Post et al. 2019, AMAP 2021, IPCC 2021). This intense warming promotes shrub growth and favours the invasion of shrubs at the uppermost limit of distribution, leading to broad-scale increases in biomass and dwarf shrub cover (Elmendorf et al. 2012, Bjorkman et al. 2018), potentially affecting the uptake and storage of atmospheric CO_2 as well as landscape greening and associated feedback cycles (Bjorkman et al. 2018, Gamm et al. 2018, Zhang et al. 2018, Post et al. 2019, Myers-Smith et al. 2020, Dobbert et al. 2022a). Since 2006, several dendroecological studies have been conducted in the Norwegian alpine focusing on shrub growth to gain a better insight into possible future vegetation shifts and site-specific adaptations (Bär et al. 2006, 2007, 2008, Weijers et al. 2018, Dobbert et al. 2021a, 2021b, 2022b, 2022c). In this context, the potential of *Betula nana* (Linné) for dendroecological studies has been tested (Meinardus et al. 2011). Here, we present annual ring widths data of the deciduous, arctic-alpine dwarf shrub *B. nana*, which has a near circumpolar distribution (Hultén 1968, see Büntgen et al. 2015 for distribution maps) and exerts considerable effects on tundra communities (Bret-Harte et al. 2001, Wahren et al. 2005). Thus, it may play a key role for the greening and browning trends observed in the region (Crawford 2008, Myers-Smith et al. 2015, Hollesen et al. 2015), and has therefore been excessively studied in recent years (Bret-Harte et al. 2001, Hollesen et al. 2015, Cahoon et al 2016, Li et al. 2016, Daniels et al. 2018, Buchwal et al. 2022, Magnússon et al. 2023, Power et al. 2024).

In Central Norway, *B. nana* dominates large parts of the alpine ecosystems (Gjærevoll 1956) and occurs across a broad range of micro-habitats (Löffler et al. 2020), probably because it is able to tolerate comparatively low winter temperatures, varying snow cover thickness, and harsh winds to a certain extent (Andrews et al. 1980, Stushnoff & Junttila 1986, de Groot et al. 1997, Ögren 2001, Bär et al. 2007).

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However, it has been shown to prefer rather moderate site conditions (Dierssen 1996), and to react positively to climate warming (Wahren et al. 2005). Löffler and Pape (2020) found a wide realized thermal niche for this species with optimum summer shoot zone temperatures of >16.4°C, and summer root zone temperatures >6.2°C, respectively. This emphasized the crucial role of thermal conditions in autumn and winter, suggesting that *B. nana* is snow-covered and/or physiologically inactive during this phase of the year.

2 Study areas

The presented dataset is based on specimens taken from two study regions located in two contrasting alpine regions of central Norway. To the east, the Vågå/Innlandet region (61°53'N; 9°15'E) is located within the continental climatic part of Norway, characterized by comparatively high aridity (Löffler 2003). To the west, the second study region, the Geiranger/Møre og Romsdal region (62°03'N; 7°15'E), is located within the slightly to markedly oceanic climatic section of the inner fjords. It is characterized by humid conditions (Löffler 2003).

3 Methods and techniques

As part of our long-term alpine ecosystem research program in central Norway (LTAER-NO; Löffler et al. 2021), we collected 143 *B. nana* specimens for our ring width measurements at the base segment of the specimens (Fig. 1), which is thought to integrate the growth of the whole plant (cf. Ropars et al. 2017). Corresponding to the heterogeneous alpine topography in the study area, we collected the specimens from four different micro-topographic positions (ridge, south-facing slope, north-facing slope, depression; Löffler et al. 2021) between 700 m a.s.l. and 1150 m a.s.l. in the West and between 1029 m a.s.l. and 1510 m a.s.l. in the East. We collected the first specimens (five to six at each site) in 2017 and plan to add more in the future.

To obtain permanent histological preparations, we cut thin sections of 15 to 20 µm from all our samples. According to standardized protocols (Schweingruber & Poschlod 2005, Gärtner & Schweingruber 2013), we stained the sections with Safranin and Astra Blue and embedded them in Euparal. We captured images of each section with an optical microscope (Keyence VHX-5000), using 100 x magnification.

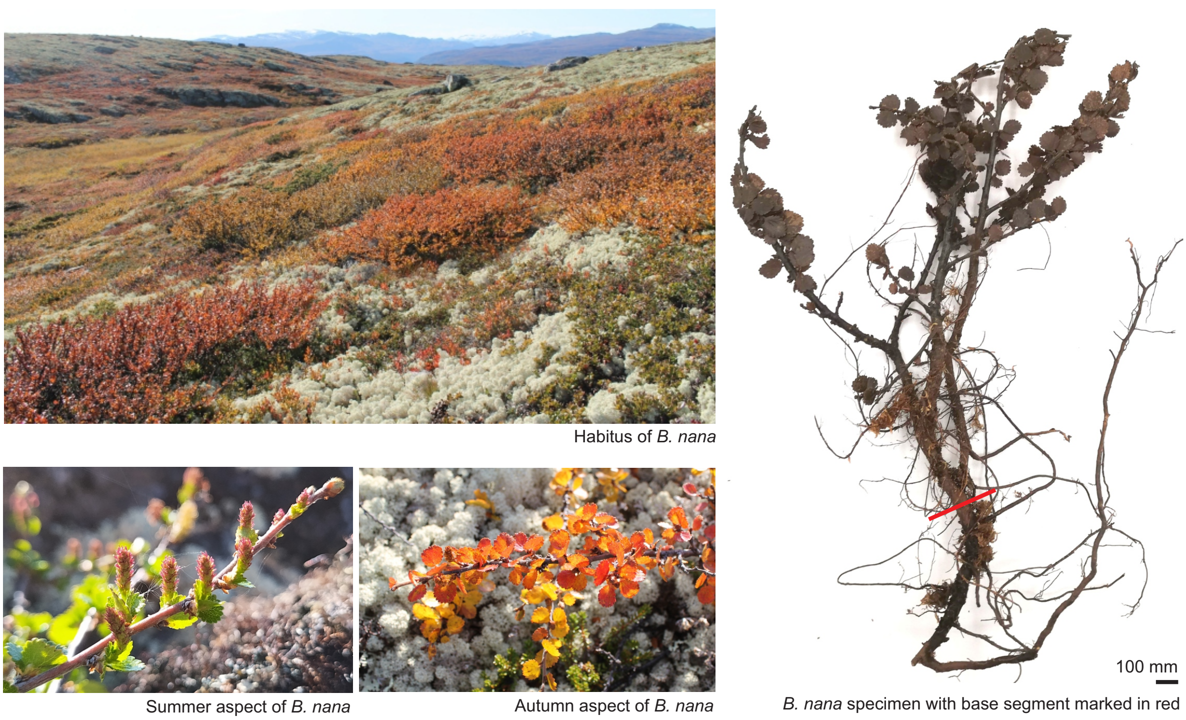

Fig. 1: Photos of *B. nana*, showing the habitus of the species, its seasonal aspects, and the structure of its below- and aboveground biomass with the base segment used for our ring width measurements. *B. nana* is a deciduous, prostrate shrub up to 1 m in height with stiff, dull dark brown twigs and orbicular or obovate-orbicular dark green leaves that turn yellow and red during autumn shortly before leave shedding (de Groot et al. 1997). The root system of the species penetrates to a depth of 40 to 45 cm, but the majority of the root system is only 10 to 20 cm deep (Ejankowski 2008).

Comparable with previous ring width measurements on alpine shrubs in the Mediterranean biome (Albrecht et al. 2023b) and in the Tundra biome (Kühnapfel et al. 2023), we measured the annual ring widths along four *radii* up to the pith, evenly distributed across each entire section (Fig. 2). In this way, we obtained 572 individual annual ring width curves along the four *radii*, which we aligned in a first cross-dating step by inserting missing and wedging rings when we identified appropriate anatomical evidence, before averaging them to obtain annual time series of each section. For detected missing rings and wedging rings, we added 7.561 µm to the time series, which was the smallest measured value of the entire dataset (Buchwal et al. 2013). As such, we obtained a total of 143 time series of annual growth increments for *B. nana*, which we visually cross-dated to determine the specimens´ age and growth patterns by a) comparing the five to six time series of each site with each other, and by b) comparing the obtained site chronologies with those of the same topographic positions. During this process, we again checked for missing and wedging rings, which we inserted if evidence emerged from comparing the time series of each site and topographic position. In this way, we obtained chronologies representing the species´ growth patterns across a large variety of different sites along multiple geographical gradients.

The xylem of *B. nana* is typically diffuse and less common semi-ring porous, and annual rings are clearly visible as delimited by 1–2 layers of parenchyma cells (Bhat & Kärkkäinen 1982; Fig. 3), unless the rings are wedged. The vessels occur solitary or in clusters of 2-3 or 4 vessels with thick walls and rays are uniseriate and/or multiseriate, consisting of 1, 2 or 3 cells (Bhat & Kärkkäinen 1982). The species´ pith is often asymmetrical and usually located in the centre of the cross section.

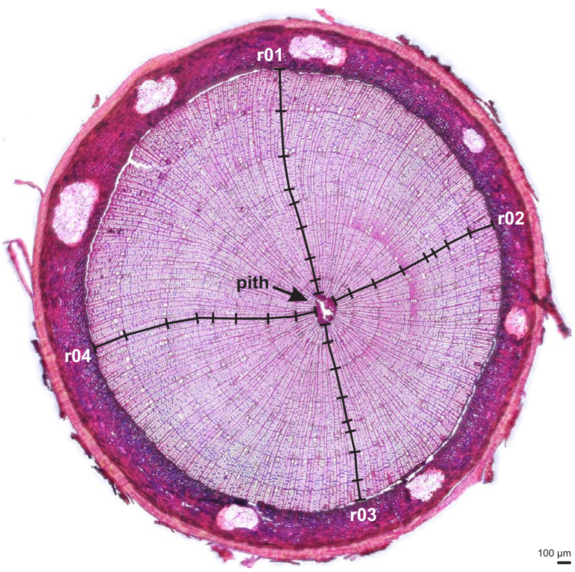

Fig. 2: Cross section of a base segment of *B. nana* collected in the East at 1319 m a.s.l. with measurements of four *radii* (r01 – r04) and marked pith, the measurement of which was excluded from the dataset before analysis.

4 Data structure

Our dataset is organised according to the following attributes.

id
Unique identifier in the form: country code (NO for Norway), study region (E = Eastern study area, Vågå/Innlandet region, W = Western study area, Geiranger/Møre og Romsdal region), elevation [m a.s.l.], position (A = ridge, B = depression, C = south-facing slope, D = north-facing slope), species ("Bnan"), number representing the sampled stem (00 – 05), intra-plant segment (e.g., nB01 for the first segment at the base of the stem), and measured radius (01 – 04).

region
Study region in which the specimens were sampled (Vågå/Innlandet region or Geiranger/Møre og Romsdal region).

elevation
Elevation in meters above sea level [m a.s.l.].

species
Monitored shrub species: *Betula nana* (Linné).

position
For description of topographic positions see Löffler et al. (2021).

segment
Intra-plant segment (base).

radius
Measured radius (01 – 04).

year
Year of ring formation (after visual cross dating).

ringWidth
Ring width [µm], measured along four radii and subsequently averaged.

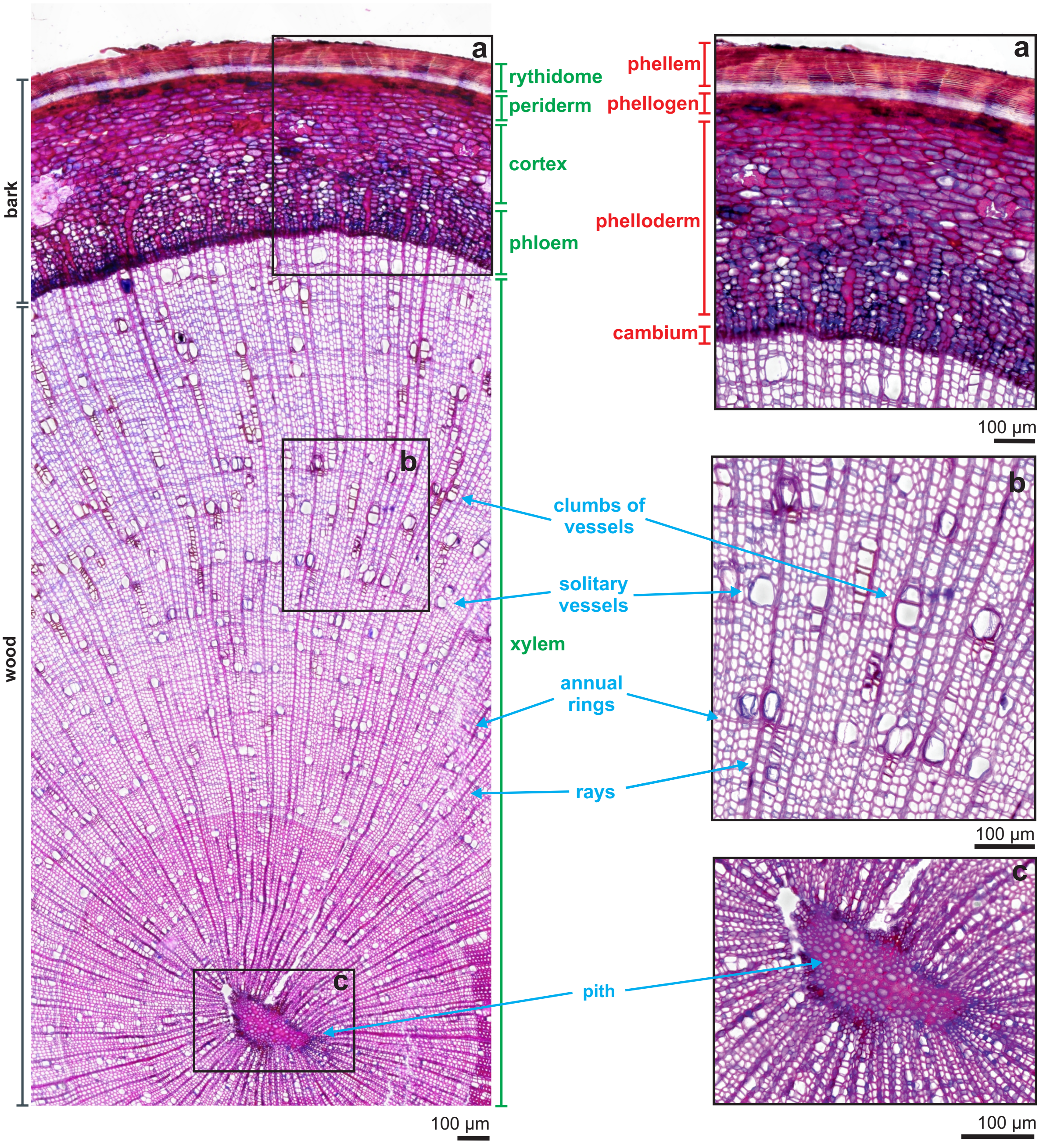

Fig. 3: Cross section of a base segment of *B. nana* showing the species´ anatomical features with (a) clearly structured bark, (b) clearly visible annual rings delimited by 1-2 layers of parenchyma cells vessels, and (c) an asymmetrical pith located in the centre of the section.

5 Dataset

Here, we publish a current dataset as part of an ongoing long-term project, and our dataset will be updated, and is as a dataset supplement available online via: https://doi.org/10.3112/erdkunde.2024.ds.01

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