UMEÅ UNIVERSITET

# Seasons Omitted

## Seasonality of Arctic Plant Activity and Nitrogen Uptake Beyond Summer

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Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i Hörsal NAT.D.470, byggnad Naturvetarhuset.
Fredagen den 7 februar, kl. 09:00.
Avhandlingen kommer att försvaras på engelska.

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**Organization**
Umeå University
Department of Ecology and Environmental Science

**Document type**
Doctoral thesis

**Date of publication**
17 January 2025

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## Title
Seasons Omitted: Seasonality of Arctic Plant Activity and Nitrogen Uptake Beyond Summer.

## Abstract
In boreal and arctic ecosystems, the seasons experience pronounced temporal variation, leading to high variability in environmental conditions. Plants are challenged by a short (aboveground) growing season during the summer and an extended period of cold temperatures, low light or snow cover during the long winter. Furthermore, nutrients are scarce and highly contested. Plants have evolved a range of mechanisms to survive and grow even in these harsh conditions, and both vascular plants and bryophytes may be able to use the "shoulder seasons" of spring and autumn. Yet, much of the research has focused on the processes during the summer season and less on seasons beyond; the full extent of annual seasonal variation in plant activity remains unexplored.

In this thesis, I explore three aspects of plant seasonal activity in a low arctic ecosystem in Northern Sweden. I traced root potential nitrogen (N) uptake in vascular plants by using isotopic $^{15}N$ labelling over multiple points throughout the year in the field. Furthermore, I explored two aspects of bryophyte activity in a range of species throughout a year: $N_2$-fixation, measured with the acetylene reduction assay, as well as photosynthesis.

My results show that vascular plants can acquire N at any time during the year in equal proportions, and potentially even more efficiently in winter. Bryophytes are less active in the middle of the winter, but activity in both photosynthesis and $N_2$-fixation peaks in the shoulder seasons for a majority of species. Interestingly, some species show activity even in the early and late winter. In contrast activity during the summer is much more limited, potentially because of drought, for many bryophyte species.

Overall, winter—a season often omitted from studies in boreal and arctic ecosystems—is as important for plant activity as summer, if not more so given its longer duration. To fully understand plant activity in these high-latitude ecosystems, the winter season has to be considered. The results from the vascular plants show that there is a temporal mismatch in the acquisition of nutrients and carbon, while bryophytes display a continued ability to acquire both nutrients and carbon. This has implications for understanding plant growth and survival in these ecosystems along with carbon and N dynamics. The concepts of growing season and "winter" should shift towards a more nuanced seasonal aspect where activity during the winter season is integrated and considered.

## Keywords
Nitrogen cycle, $^{15}N$ tracer, winter, plant-microbe interaction, bryophytes, $N_2$-fixation, acetylene reduction assay, photosynthesis

**Language**
English

**ISBN**
print: 978-91-8070-565-3
PDF: 978-91-8070-566-0

**Number of pages**
42 + 3 papers