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The Effect of Temperature, Water Content, and Light Intensity and Quality on Nitrogen Fixation in High Arctic Vegetation

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Introduction

Nitrogen is a key controlling factor for terrestrial primary production in the Arctic. Due to general low precipitation in arctic regions, deposition of nitrogen is not sufficient. Thus, biological nitrogen fixation plays an important role and contributes up to 50% of the nitrogen. Due to the lack of legumes in high arctic ecosystems, nitrogen fixation by free-living, epiphytic (moss-associated) (Fig. 6) or symbiotic (lichen) cyanobacteria is considered to be the main source of biologically fixed nitrogen. Models of future climate predict significant changes in the climate conditions in the Arctic. Changes in different climate factors may have either a stimulating or an inhibiting effect on the nitrogen fixation activity in high arctic environments. In this study we investigated the effect of temperature, soil water content, and light quantity and quality on nitrogen fixation in different types of vegetation on Svalbard, High Arctic.

Fig. 1: Localisation of Svalbard in the northern hemisphere.

Materials and Methods

To study the effect of abiotic factors on the nitrogen fixation activity of epiphytic cyanobacteria, vegetation samples from different types of common arctic plant communities were collected in the Sassen Valley (Fig. 2). This valley is situated in Central Svalbard (78°17'N, 16°00'N) (Fig. 1) and represents one of the reproductive areas of this archipelago. The samples were incubated under controlled conditions, i.e. temperature gradient, moisture gradient, and light gradient, and then assayed for nitrogen fixation activity using the acetylene reduction assay. This assay is an indirect method whereby the amount of produced ethylene is a measure for the nitrogen fixation rate.

Fig. 3

Fig. 2

The experimental site for studying the effect of enhanced UVB-radiation of nitrogen fixation activity is located in the Advent Valley (Central Svalbard), another reproductive area characterized by dense moss vegetation (Fig. 3). In 1996 eight metal frames each equipped with six UVB fluorescent tubes were set up on the vegetation on the valley floor. The experimental setup simulates an enhanced UVB radiation corresponding a 15% depletion of the atmospheric ozone layer. The seasonal changes in solar radiation were simulated by using timer-controlled power control. Four of the eight metal frames served as control treatments. In these plots the artificial UVB radiation were filtered out by mounting glassplates under the fluorescent tubes.

Results

The vegetation samples showed a low, but detectable ethylene production already at 0°C. From about 10°C ethylene production rates increased until they reached an optimum at a temperature between 25°C and 32°C depending on the type of vegetation (Fig. 5a). Moreover, samples from all studied types of vegetation showed a common linear correlation between the amount of water added to the dried samples and the ethylene production. Both samples from wet habitats and samples from vegetation characterized by low natural water content showed the same response on the added water (Fig. 5b). The studied samples showed a clear response to varying light intensities. Between the maximum experimental value (230 µmol photons m^{-2} s^{-1}) and a light intensity of about 120 to 80 µmol photons m^{-2} s^{-1} depending on type of vegetation, the ethylene production was almost constant. Decreasing the light intensity to total darkness the ethylene production rapidly dropped to zero (Fig. 5c). Nitrogen fixation capacity of moss-associated cyanobacteria was significantly reduced at enhanced UVB radiation (Fig.5d). The results shown are after enhanced UVB during six growing seasons, but similar results were already observed after 2 and 3 years. (Error bars are omitted for better clarity)

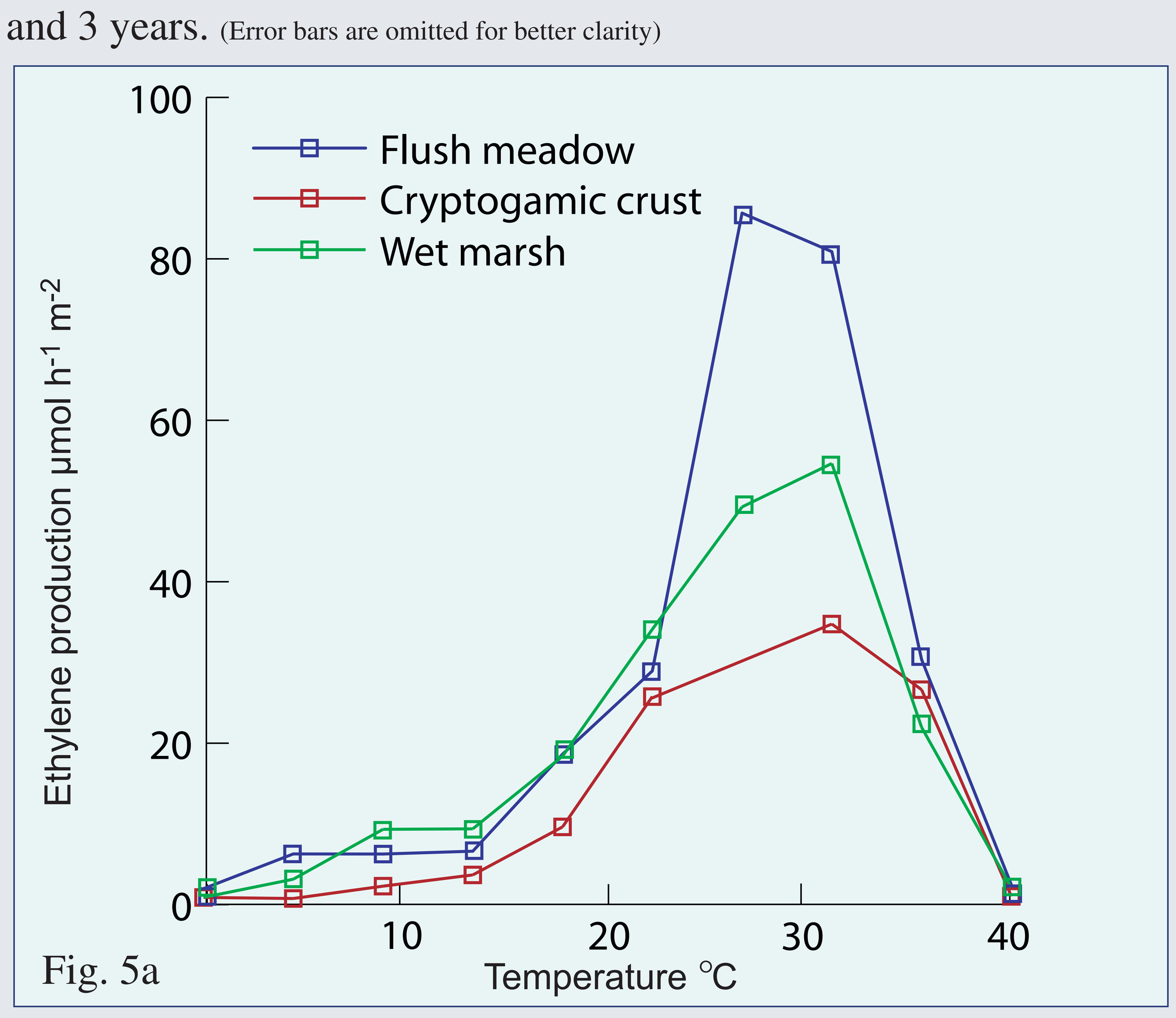

Fig. 5a

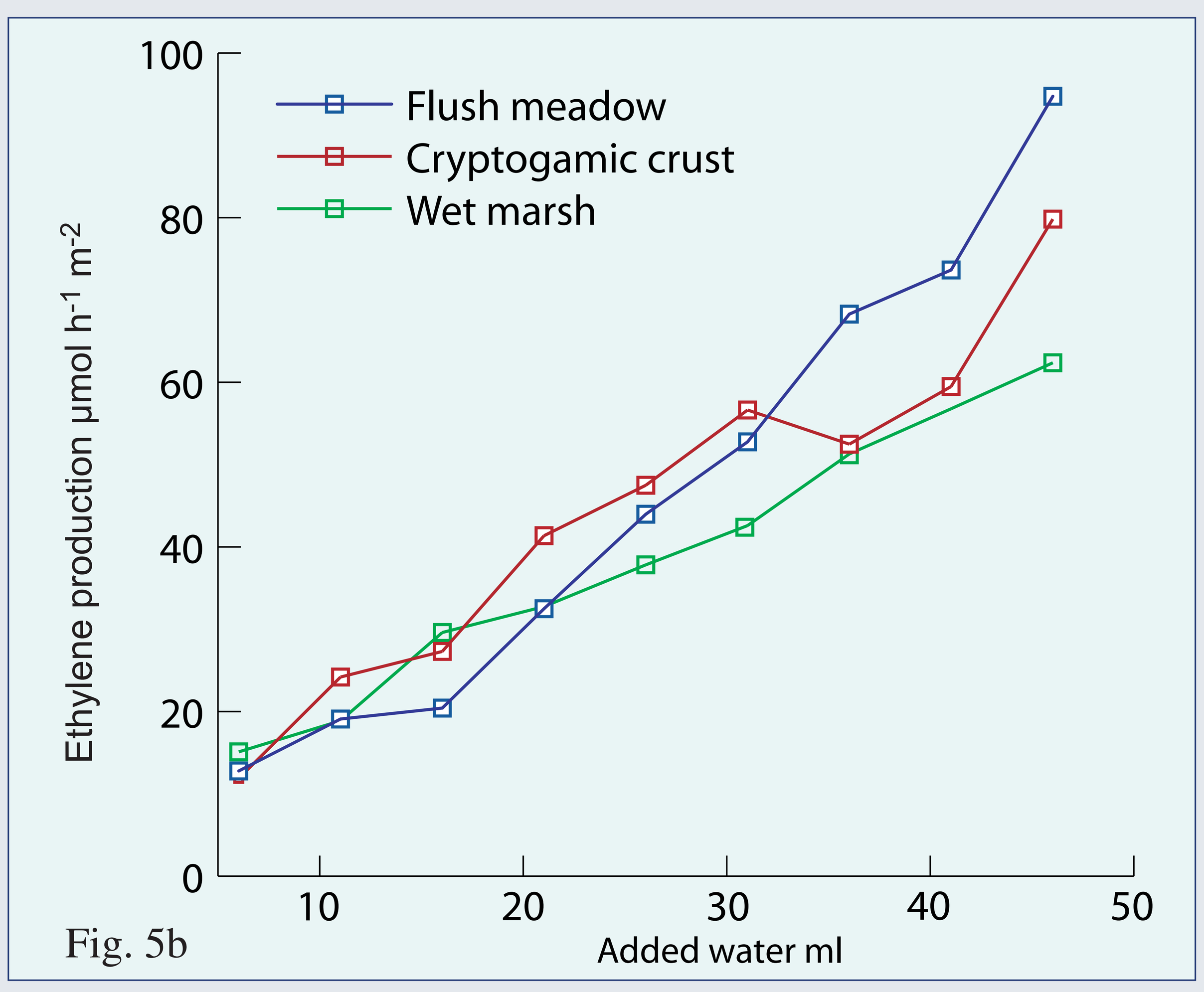

Fig. 5b

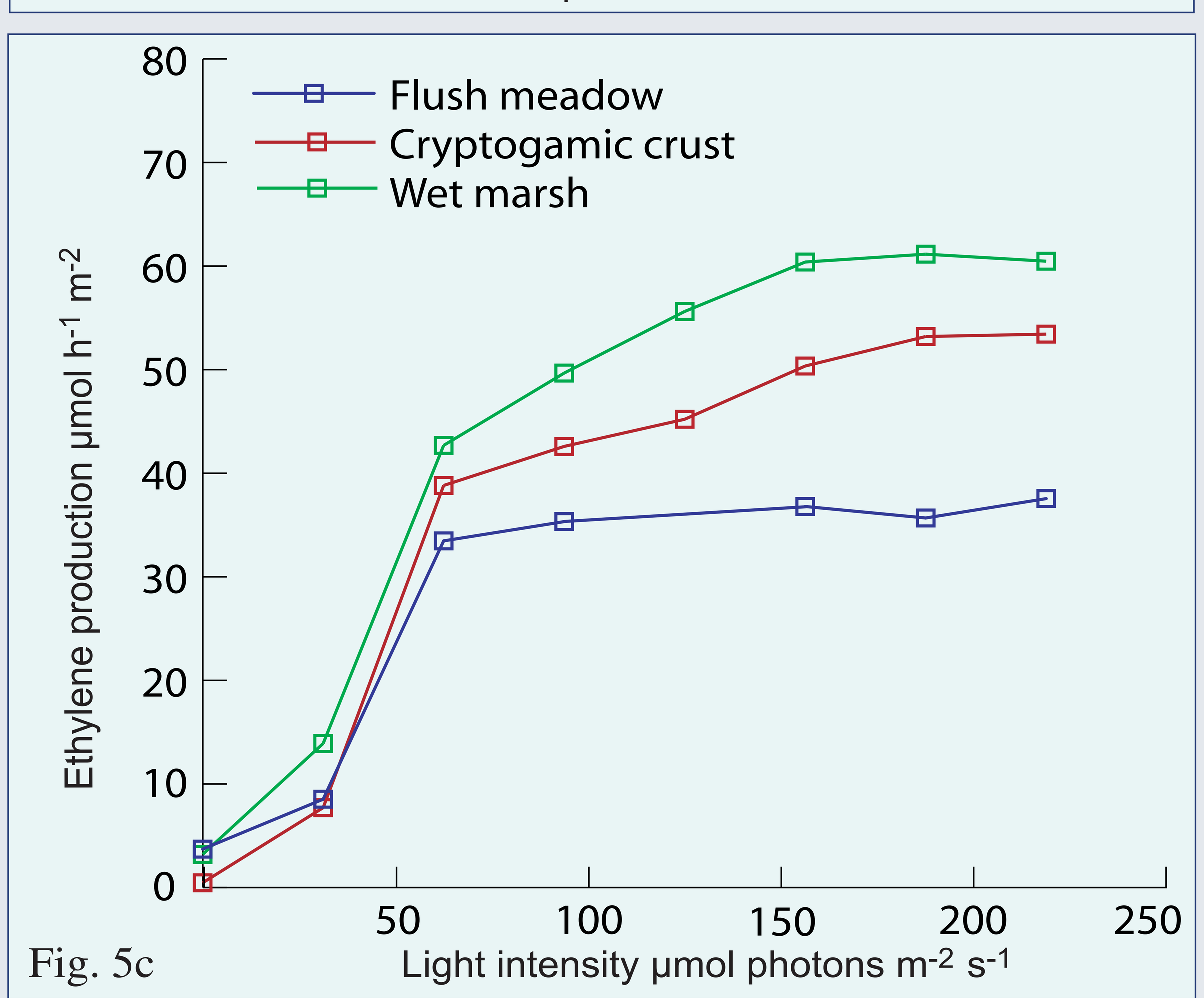

Fig. 5c

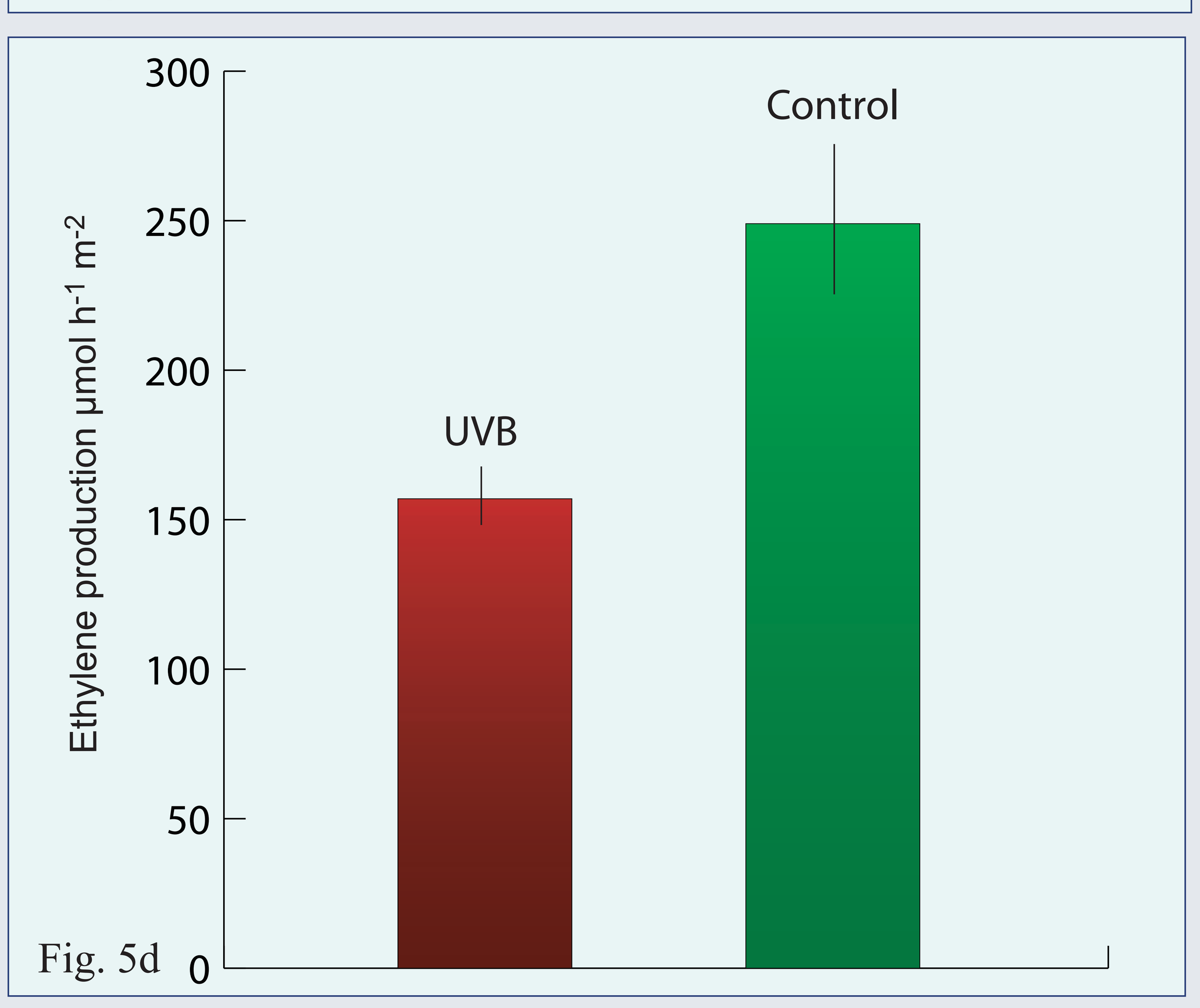

Fig. 5d

Discussion and conclusions

- The results from the temperature gradient show that epiphytic cyanobacteria do not have a temperature optimum adapted to the natural conditions on Svalbard. Moreover, the nitrogen fixation activity is almost constant between 0°C and 15°C. This and the fact that mean temperature at 1 cm depth in the vegetation layer at the sampling sites during the growing season is between 0°C and 12°C indicate that nitrogen fixation is temperature-independent during most of the growing season.
- Taking the low annual precipitation in central Svalbard (below 300mm) into account, the response of nitrogen fixation on an increased water content of the vegetation shows that moisture are an important factor for nitrogen fixation in these environments.
- Since the light intensity through the 24h-photoperiod during the growing season on Svalbard is mostly well above the critical value (140 µmol photons m^{-2} s^{-1}) this factor seems not to be limiting for nitrogen fixation in this area.
- The results from the UVB-experiments clearly show that the simulated enhanced UVB-radiation, which is well inside the predicted increase due to ozone depletion, has a dramatic effect on the process of nitrogen fixation.

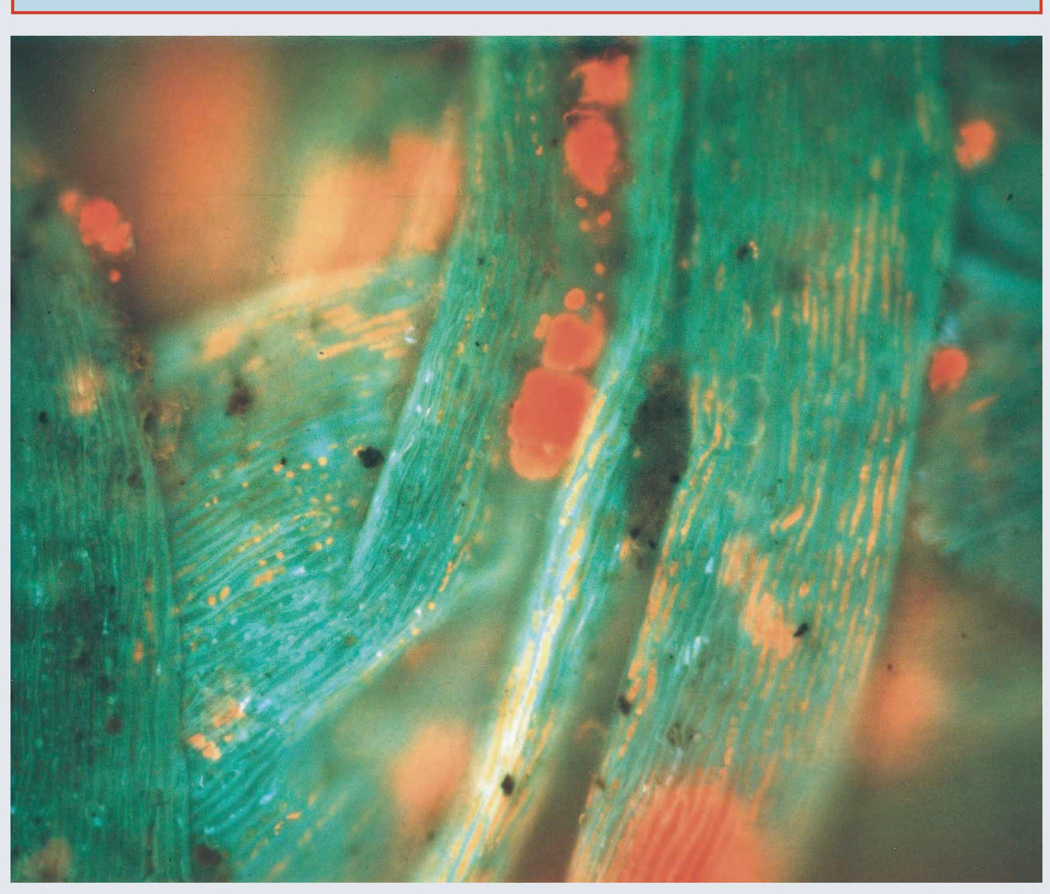

Fig. 6: Fluoerescent micrograph of epiphytic cyanobacteria on moss-leaves.