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Short Communication

Response of plant production to growing/non-growing season asymmetric warming in an alpine meadow of the Northern Tibetan Plateau

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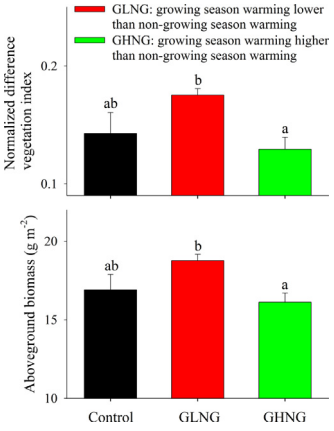
HIGHLIGHTS

- NDVI/AGB and SAVI/GPP had varied responses to season asymmetric warming.
- Non-growing season with a higher-level warming had greater effects on NDVI and AGB.
- NDVI/AGB differences were due to varied effects on water, N and temperature.

GRAPHICAL ABSTRACT



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ABSTRACT

A field growing/non-growing season asymmetric warming experiment (C: control, i.e., no warming in the entire year; GLNG: growing season warming lower than non-growing season warming; GHNG: growing season warming higher than non-growing season warming) was conducted in an alpine meadow of the Northern Tibetan Plateau in early June 2015. The effects of growing/non-growing season asymmetric warming on the normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI), aboveground biomass (AGB) and gross primary production (GPP) in 2015–2017 were examined. The 'GLNG' and 'GHNG' treatments significantly increased the annual mean air temperature (T_a) by 2.95 °C and 2.76 °C, and the vapor pressure deficit (VPD) by 0.23 kPa and 0.28 kPa but significantly reduced the annual mean soil moisture (SM) by 0.02 m^3 m^{-3} and 0.02 m^3 m^{-3} respectively; however, changes in the annual mean T_a, VPD and SM were the same between the 'GLNG' and 'GHNG' treatments over the three years in 2015–2017. There were no significant differences in the SAVI and GPP among the 'C', 'GLNG' and 'GHNG' treatments over the three growing seasons in 2015–2017. The 'GLNG' and 'GHNG' treatments did not significantly affect the NDVI and AGB compared to 'C', whereas the NDVI and AGB under the 'GLNG' treatment were significantly greater than those under the 'GHNG' treatment over the three growing seasons in 2015–2017. The significant differences in NDVI and AGB between the 'GLNG' and 'GHNG' treatments may be attributed to the different effects under the 'GLNG' and 'GHNG' treatments

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on the non-growing season T_a, growing season water availability and soil nitrogen availability. Therefore, the non-growing season with a higher warming magnitude may have stronger effects on the aboveground plant production than did the growing season with a higher warming magnitude in the alpine meadow of the Northern Tibetan Plateau.

1. Introduction

Due to global warming, the surface temperature of the Tibetan Plateau has experienced an obvious increase during the past decades and is predicted to continue to increase by the end of this century (Diffenbaugh and Field, 2013). The warming magnitudes vary by season on the Tibetan Plateau (Wang et al., 2010). Although a growing number of field warming experiments are used to examine the effects of climatic warming on plant production in the alpine ecosystems (Fu et al., 2015; Yang et al., 2018), only a few studies have investigated the response of the aboveground biomass (Zong et al., 2018) to winter warming in the alpine meadows of the Tibetan Plateau. Different indicators of plant production may have different temperature sensitivities and responses to experimental warming (Wang et al., 2017; Wu et al., 2011). No studies have compared the responses of different plant production indicators to seasonal asymmetric warming under controlled warming conditions in the alpine grasslands of the Tibetan Plateau. Therefore, it remains unclear how plant production will respond to seasonal asymmetric warming in the alpine grasslands of the Tibetan Plateau.

In this study, a growing/non-growing season asymmetric warming experiment was carried out in an alpine meadow of the Northern Tibetan Plateau. The main objective of this study was to examine the effects of seasonal asymmetric experimental warming on plant production (i.e. the normalized difference vegetation index (NDVI), the soil adjusted vegetation index (SAVI), the aboveground biomass (AGB) and the gross primary production (GPP)).

2. Materials and methods

2.1. Study area, experimental design and microclimate measurements

The climate, soil and vegetation characteristics around the study area were reported in our previous study (Fu et al., 2012). This experiment was started in early June 2015. There were three treatments with three replicates, including the control (C), the growing season (June–September) warming lower than the non-growing season warming (GLNG) treatment, and the growing season warming higher than the non-growing season warming (GHNG) treatment. We used

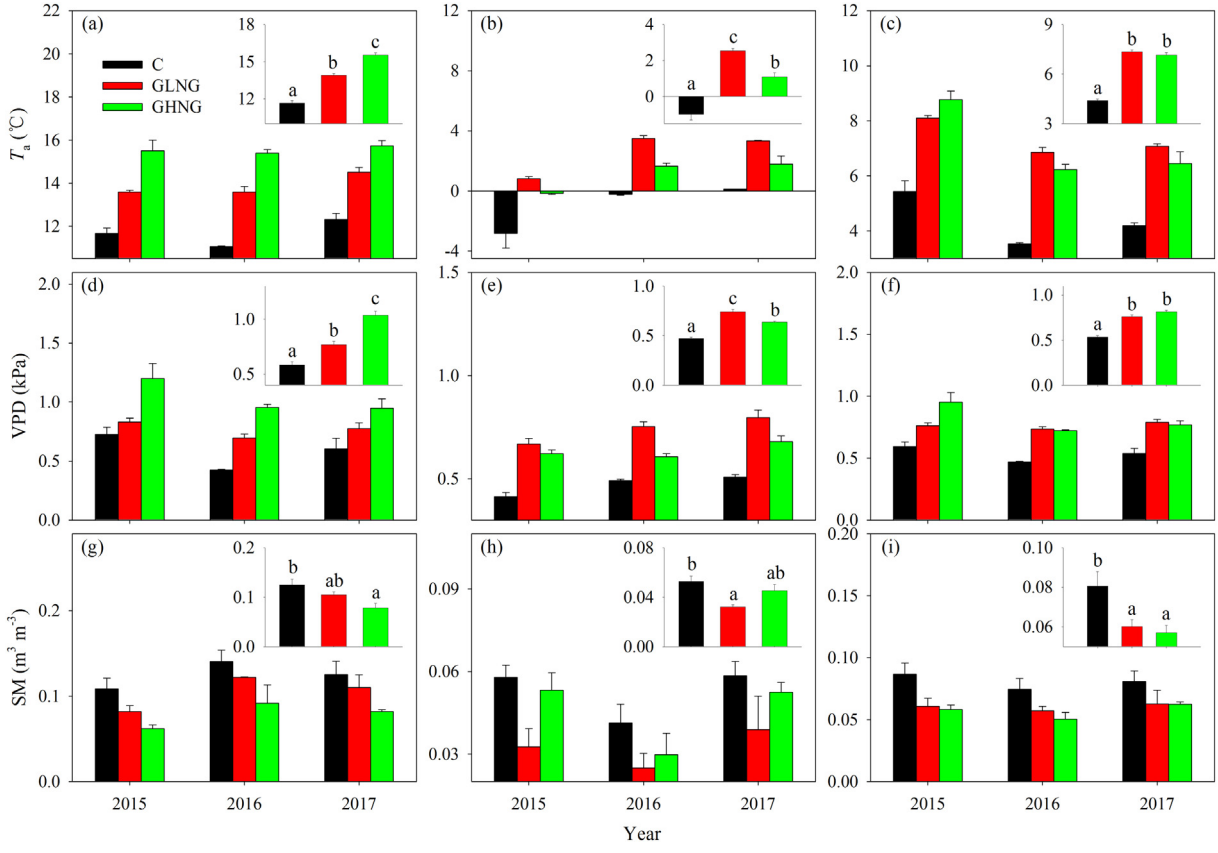

Fig. 1. Comparison of (a) the growing season average air temperature (T_a), (b) the non-growing season average T_a, (c) the annual average T_a, (d) the growing season average vapor pressure deficit (VPD), (e) the non-growing season average VPD, (f) the annual average VPD, (g) the growing season average soil moisture (SM), (h) the non-growing season average SM, and (i) the annual average SM among the three experimental warming treatments. The inset plot in each subfigure was the average data throughout the three-year period of 2015–2017. Different letters in the inset plots implied that there were significant differences at $p < 0.05$. C: control, i.e., no warming in the entire year; GLNG: growing season warming lower than non-growing season warming; GHNG: growing season warming higher than non-growing season warming.