Referee's comments in black
Authors' responses in blue

Responses to Tariq Munir (Referee 1)

General comments

This manuscript is very well articulated, and it will attract readers working on plant PFT/traits responses to permafrost thaw and subsequent nutrient concentration in gelisols in the event of climate warming. The paper adds to our knowledge about how shrubs will respond to climate warming with their strategies to fight back by trading-off between traits for their sustained growth.

We thank Tariq Munir for taking the time to read and comment on our manuscript.

The manuscript does not describe how many times and how frequent the experimental sites were visited during the study years to imagine the field-work extent of this manuscript which tries to provide many solid conclusions. Without this information, it looks like the sites were set up and flowed by a couple of campaigns each year.

The experimental site was visited periodically during the study years as described in the reference we included in Line 101 (Wang *et al.*, 2017). The campaigns were limited to the growing season; due to the harsh conditions of the study area, the experimental plots were not accessible during the rest of the year. Below, we enumerate the visits to the plots (information extracted from Wang *et al.*, 2017).

The experimental plots were selected in July 2010; the heating cables were inserted in the soil also in this period. The following growing season (July 2011), the experimental treatments (heating and fertilization) were implemented in July 2011: the heating cables were connected to the solar panels in the heated plots and slow-release NPK fertilizer tablets were added to the fertilized plots. In 2013, nutrients were added again to the plots. During the experimental period, environmental factors were measured periodically. The permafrost thaw depth and soil moisture were measured 2-4 times per growing season, while soil temperature was measured continuously (data were recovered from the temperature loggers each growing season). Resin bags to assess soil nutrient availability were inserted in each plot in 2010 and replaced by new ones at the beginning of each August until 2014. The species abundance within the plots was recorded in 2010 and 2013 (results published in Wang et al., 2017). Aboveground and belowground biomass was harvested in August 2014 (Wang *et al.*, 2017). The individuals selected for the plant trait analysis and growth rate (Iturrate-Garcia *et al.*, 2017) were sampled in the second half of 2014 growing season (31 July - 12 August 2014), when leaf and stem traits were also measured (indicated in Lines 128-129).

The above information will be added to section 2 Materials and Methods (subsections 2.2 Experimental design and 2.4 Study species and sampling).

Iturrate-Garcia, M., Heijmans, M.M.P.D., Schweingruber, F.H., Maximov, T.C., Niklaus, P.A., Schaepman-Strub, G. (2017). Shrub growth rate and bark responses to soil warming and nutrient addition – A dendroecolological approach in a field experiment. *Dendrochronologia*, 45, 12-22.

Wang, P., Limpens, J., Mommer, I., van Ruijven, J., Nauta, A.L., Berendse, F., Schaepman-Strub, G., Blok, D., Maximov, T.C., Heijmans, M.M.P.D. (2017). Above and belowground responses of four tundra plant functional types to deep soil heating and surface soil fertilization. *Journal of Ecology*, 105, 164−175.

No pre-experimental conditions of the selected blocks are provided (if they were similar of different with some statistical analyses) which could be another drawback of this research.

Although no pre-experimental condition of the selected blocks are provided, potential differences within blocks were statistically considered by including "block" (factor with 5 levels) as fixed term in all the linear mixed-effect models. Moreover, in order to take into account species-specific trait differences among blocks, we added the interaction between species and block (fix terms) to the statistical models, which we run for plant traits (detailed in subsection "2.6 Statistical analysis").

The statistical analyses/models performed might need a quick look back or rerun with random effects. There are no repeated measurements over the years I know of.

Except for the statistical models used to test the effects of treatments on soil temperature and permafrost thaw depth (see explanation at specific comment further down, referring to Line 166-170), the other statistical models (effects of treatments on plant traits) consider plot as random effect, as described in subsection "2.6 Statistical analysis". It is correct that there are no repeated measurements over the years.

Specific comments

Paras 2-3: resource acquisition and conservative strategies of plants. do authors have references to these strategies studied

We will add the reference of Diaz *et al.* (2016) on Line 44, which refers to acquisitive and conservative strategies of plants.

Díaz, S., Kattge, J., Cornelissen, J.H.C., Wright, I.J., Lavorel, S., Dray, S. et al. (2016). The global spectrum of plant form and function, *Nature*, 529, 1-17.

Line 52. Would you like to put a reference for projected conditions?

We will add the article by Post *et al.* (2019) on Line 52, as a reference for projected conditions in the Arctic.

Post, E., Alley, R.B., Christensen, T.R., Macias-Fauria, M., Forbes, B.C., Gooseff, M.N., Iler, A., Kerby, J.T., Laidre, K.L., Mann, M.E., Olofsson, J., Stroeve, J.C., Ulmer, F., Virginia, R.A., Wang, M. (2019). The polar regions in a 2°C warmer world. *Science Advances,* 5, eaaw9883.

Line 54. I would better put a semi-colon here instead of two parentheses

OK

Line 62. Please correct referencing here I know, one can derive specific objectives form the last paragraph of hypothesis and an overview of the experimental components; however, I would better explicitly mention specific objectives helpful for researchers skimming several studies at a time

If we understood correctly, in this comment Taquir Munir (Referee 1) raises his concern about using solely the reference Violle et al. (2007) instead of adding several studies at a time. The inclusion of this reference, however, aims to clarify the concept of trait used in the studies related to tundra shrub responses to climate change. Violle et al. (2007) is a theoretical/review paper. This paper introduces the concept of "performance traits" and specifically elaborates on traits included in this category. Addressing the suggestion of the received Short Comment by Michael O'Brien (L62), we rephrased the sentence ('[…] performance traits (detailed in Violle et al., 2007) […]"), which might help to address also the comment by Taquir Munir.

In case that this comment refers to Line 74 instead of Line 62, we will rephrase the sentence to specifically mention the objectives of the study. 'The objective of this study is to experimentally investigate…'

Line97. Define growing season (e.g., May-Oct); I think, it must be a point when the daily maximum temperature reaches a minimum of 6-degree C. The growing season was never defined except table 1

We use the term "growing season" for the period of the year during which arctic plants photosynthesize and grow. The timing of the growing season depends on the air temperature, snowmelt, and thawing of frozen soil at the study site. Air temperature (e.g. 6°C) alone is therefore not an appropriate proxy for the growing season and it can vary from year to year (± 4 days; Parmentier *et al.* 2011) and from species to species. For the research area at the ecosystem level, the growing season lasts approximately from end of June to end of August, based on carbon flux analyses (Parmentier *et al*. 2011, van der Molen *et al*. 2007).

To address the referee's comment we will add an indication of time on Line94: '...and lichens. The growing season lasts from the end of June to end of August. The slightly acidic soil...'

Parmentier, F.J.W., van der Mole, M.K., van Huissteden, J., Karsanaev, S.A., Kononov, A.V., Suzdalov, D.A., Maximov, T.C., Dolman, A.J. (2011). Longer growing seasons do not increase net carbon uptake in the northeastern Siberian tundra. *Journal of Geophysical Research*, 116, G04013.

van der Molen, M.K.; van Huissteden, J., Parmentier, F.J.W., Petrescu, A.M.R., Dolman, A.J. *et al.* (2007). The growing season greenhouse gas balance of a continental tundra site in the Indigirka lowlands, NE Siberia. *Biogeosciences*, European Geosciences Union, 4 (6), pp. 985−1003.

Line102. What was the extent of a block? A schematic may help here

The six plots within each block were spaced by 1-2 meter distance from each other. With a size of 1.5 m x 1.5 m, all plots within a block were located in an area of approximately 10 m x 10 m. A picture of a typical block setup is contained in the supplementary material of Wang *et al.*, 2017. We will add the approximate extent of blocks to the experimental design section.

Wang, P., Limpens, J., Mommer, I., van Ruijven, J., Nauta, A.L., Berendse, F., Schaepman-Strub, G., Blok, D., Maximov, T.C., Heijmans, M.M.P.D. (2017). Above and belowground responses of four tundra plant functional types to deep soil heating and surface soil fertilization. *Journal of Ecology*, 105, 164−175.

Line105. How heating cables were buried? I hope sunny days were long enough to charge batteries and the batteries never failed

A detailed description of the experimental set-up and burying of the heating cables, including pictures, is provided in the reference indicated in L101 (Wang *et al.* 2017, including

supplementary materials). The heating cables were buried into the soil from trenches excavated at two opposing sides of the experimental plots to minimize disturbance within the plots (i.e. disturbance of roots and microbial activity). For the heated cable treatment, the cables were connected to two solar panels of 85 W each, which were connected in parallel. The solar panels were installed with an angle of 60° to capture 20 hours of sunlight per day during the summer. No battery was included in the circuit. Thereby, the solar energy directly enlarged the natural ground heat flux, allowing for diurnal and seasonal variation in solar intensity.

Wang, P., Limpens, J., Mommer, I., van Ruijven, J., Nauta, A.L., Berendse, F., Schaepman-Strub, G., Blok, D., Maximov, T.C., Heijmans, M.M.P.D. (2017). Above and belowground responses of four tundra plant functional types to deep soil heating and surface soil fertilization. *Journal of Ecology*, 105, 164−175.

Line 166-170. I am afraid the random effects of the plot was not included in lme

For this statistical analysis − effects of permafrost thaw and fertilization treatments on soil temperature and thaw depth of the experimental plots – we used the average of the permafrost thaw depth and temperature data per plot as response variable. As indicated in subsection 2.3 of the manuscript, data were collected in 2013 (only temperature) and 2014 (temperature and thaw depth). Because we aggregated the data per experimental plot, we removed the random term (plot) from our analysis, in order to avoid model-overfitting.

Line 350-368. Discussion tries to relate no matter what I am trying to understand why this experiment could not be completed in less than four years when the year seems not to have any specific function, for example, repeated measurements? I know the fertilizer was applied twice, the second time after two years – other than that do not know why four years are emphasized? Stem traits did not show response even after four years anyway.

Although repeated measurements were not used in this study, the experimental duration over several years (i.e. 4 years) was important for many reasons. By running the experiment for four years, we aimed at reducing potential disturbance effects by the initial experimental setup (i.e. soil disturbance due to introduction of heating cables). Moreover, we selected a duration of several years considering the characteristics of tundra plant species, i.e. low rates of resource acquisition, growth and tissue turnover (Chapin 1980). This consideration was especially important for the shrub growth rate study associated with the experiment (Iturrate-Garcia et al., 2017). In this case, the experimental duration covered different climate conditions in the control plots across years and multiple annual growth rings. This fact allowed us to get insights into the effects of climatic conditions on growth rate (unpublished results).

As indicated in the answer addressing Referee 2's comment (L120), the aim of this study is to test treatment effects on plant traits by comparing treatment plots with control plots after 4 years of experiment and not to document relative changes for individuals over the experimental period. Because of this aim and the destructive sampling of individuals needed for the current study, we did not have repeated measurements across the years. Furthermore, we sampled only at the end of the experiment to avoid disturbing the setup.

The lack of response of stem traits, indeed, might be explained by the relative short term of the experiment, as explained in Lines 307-309. Wood tissue turnover is slower than leaf tissue (Negrón-Juárez et al., 2015). Thus, stem traits might require even more time (> 4 years) to show responses.

Chapin, F.S. III (1980). The mineral nutrition of wild plants. *Annual Review of Ecology and Systematics*, 11, 233−260.

Iturrate-Garcia, M., Heijmans, M.M.P.D., Schweingruber, F.H., Maximov, T.C., Niklaus, P.A., Schaepman-Strub, G. (2017). Shrub growth rate and bark responses to soil warming and nutrient addition − A dendroecological approach in a field experiment. *Dendrochronologia*, 45, 12−22.

Negrón-Juárez, R.I., Koven, C.D., Riley, W.J., Knox, R.G., Chambers, J.Q. (2015). Observed allocations of productivity and biomass, and turnover times in tropical forests are not accurately represented in CMIP5 Earth system models. *Environmental Research Letters,* 10, 064017.

I do not see tables S2 S3 and fig. 5 s1 mentioned in the text

The tables S2 –S3 and figure S1 mentioned in the text are included in the supplementary material: https://www.biogeosciences-discuss.net/bg-2019-498/bg-2019-498-supplement.pdf