Production efficiency of needles of two larches sp. raised under a free air Ozone fumigation system in combination with nitrogen application

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Introduction

Ozone (O_3) is a toxic air pollutant and one of main components inhibiting growth and photosynthetic activities of plants inducing defoliation and reduction of biomass. In Japan, some of highly populated cities, such as Tokyo, Osaka and those metropolis, are indicating high concentration of O_3 over 40 ppb in the atmosphere. In addition, it would exceed the threshold of toxic concentration over those metropolitan cities and industrial regions (*7*).

Given the importance and menace of O_3 to plants, edaphic condition in forest is vital to encourage larch as suitable species. Most lands in northern Japan are composed with immature volcanic soil. In terms of nutrient uptake mechanism, plants are easily exposed to poor nutrient condition (*6*). With this point, we should know effects of nitrogen (N) deposition to the growth of both larch species. By anthropogenic activities since The Industrial Revolution, N deposition has exceeded the threshold of N load, 10-30 kg N ha^{-1} yr^{-1}, in Europe. And it is considered that it would be excessive over 50 kg N ha^{-1} yr^{-1} (*5*). But, deposited N is expected to play a role as a kind of fertilizers during initial stage of N saturation.

Larch species are broadly distributed and they are main components in boreal forests in Northern Hemisphere. Larch species acclimate effectively to low nutrient in the soil, short summers for growth and photosynthetic activities, and low temperature (*8*). Hence, Japanese larch was introduced in the northern region of Japan from the central subalpine region as a trial species for afforestation, because it can grow under to low temperature and poor nutrient soil (i.e. immature volcanic ash soil). On the other hand, Japanese larch suffers from the shoot blight disease and grazing by voles. In order to improve these difficulties of Japanese larch, Hybrid larch F_1 was developed and considered as a promising species. Hybrid larch F_1 showed rapid growth rate at the early growth phase, and also, it had shown the tolerance to low temperature and to above mentioned weakness of Japanese larch (*4, 9*).

Thus, to elucidate Hybrid larch F_1 on environmental changes, we should know interactive effects of O_3 and N load to both larch species, because both O_3 emission and N deposition are projected to increase consistently in the future (*1*). Under high N condition, foliar organs usually increase (*2*). However, longevity of foliar organ is diminished by elevated O_3. Therefore, we would like to know foliar efficiency of biomass production (FPE) in two larch species. In this study, we evaluated FPE in larch species grown under elevated O_3 with nitrogen loading.

Materials and methods

1. Plant materials and treatments

Two-year-old seedlings of Japanese larch and Hybrid larch F_1 were planted on 15 L pots filled with Kanuma pumice and Akadama soil, in 1:1 volume, to simulate well-weathered immature volcanic ash soil with matched tray at late May, 2013. We gained seedlings of Japanese larch from Naganuma near Sapporo and Hybrid larch F_1 was obtained from Hokkaido Forestry Research Institute, HRO in Bibai, also near Sapporo. We planted 32 seedlings for each ambient and O_3 treatment in May, 2013.

Figure 1 Ambient treatment (left) and Elevated O_3 treatment (right) with a free-air O_3 fumigation system

For O_3 treatment, we used a free air O_3 fumigation system and the detail description was made by Watanabe *et al.* (*11*) (Figure 1). Ozone concentration of 60 nmol mol^{-1} was treated during daytime-regulated photo-sensors detecting 60 μmol $m^{-2}s^{-1}$ as of light compensation point of larch species from June to October (*8*).

For N treatment, NH_4NO_3 solution was supplied to the potted soil. Total amount of N treatment was 50 kg N ha^{-1} $year^{-1}$ and the supply was divided into 4 times with the order of 15, 20, 10 and 5 kg N ha^{-1} $year^{-1}$ from June to late September according to seasonal N accumulation pattern (*2*). For these treatments, we set 4 platforms with 4 potted plants with water trap to catch leaching water. Trapped water was re-irritated to keep the total amount of N to seedlings

2. Measurements

The diameter and height of seedling in each treatment had measured in 4 times at one-month interval from July to October, 2013. This enabled us to monitor consistently plant growth. We assessed the stem biomass based on estimated volume by diameter and height.

For dry mass of litterfall needles, 2/3 lower part of the seedlings was wrapped with 2 mm mesh clothes (Krary, Osaka, Japan) from mid-October to late November, 2013. The litterfall was dried at 80℃ in an oven during 10 days. Based on dry

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mass of needle litter, the estimated stem mass (g) via multiplication by volume (cm^3) and specific gravity of stem (JL = 0.44, HL = 0.50), followed by HRO (*3*), per needle-litter mass (g) was estimated as foliar production efficiency (FPE):

FPE= Stem mass per dry mass of needle-litter

*3. Statistical analysi*s

The interactive effects of O_3 and N on production efficiency were tested by two-way analysis of variance (ANOVA). Statistical analyses was performed with PASW software (18.0, SPSS Inc., USA.

Result and discussion

Effects of O_3 and N loading on FPE are indicated on Figure 2 (A = JL, B = HL). At elevated O_3 treatment, foliar production efficiency of Japanese larch and Hybrid larch F_1 were higher than them at ambient treatment. Small amounts of needles in both of species led to efficient aboveground production more than needles at ambient air treatment. However, there was no effect of N loading of 50 kg N ha^{-1} $year^{-1}$ on FPE at high O_3 in both larch species.

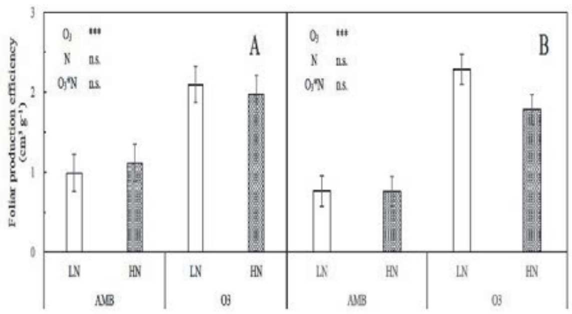

Figure 2 Foliar production efficiency of aboveground volume to the dry mass of needle litter, collected in November, 2013. Note: AMB=ambient, O3=Ozone fumigation, LN= no nitrogen application, HN= 50 $kgNha^{-1}yr^{-1}$.

Compared with elevated O_3 and ambient treatment, FPE in both of Japanese larch and Hybrid larch F_1 was significantly increased by the O_3 effect. Both larches produced aboveground biomass with limited amounts of needle litter. This may be related to restore the damage by O_3 with high photosynthetic activities utilizing nitrogen. Hence, to elucidate interactive effects of Japanese larch and Hybrid larch F_1, we should further discuss more plausible understanding on O_3 and N loading and know more detailed points over several years, because of perennial traits of larch species.

Acknowledgement

We thank to Mr. T. Ueda of DALTON Co. LTD for proper maintenance of free air O_3 fumigation system and Dr. T. Harayama of FFPRI for proper guidance. And This study was carried out in part by Earth Environmental Research Fund of Ministry of Environment (B1105) and Grant-in-aid of JSPS fund (Type B:26292075, Young Scientists B: 24710027).

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