永久凍土の“酔っ払い”トウヒは尿素を吸う

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Drunken spruce trees take up urea on permafrost soil

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Introduction and objectives: “Drunken forest” is developed on earth hummocks on shallow permafrost layer near Inuvik, Canada. Mounds and troughs are commonly formed through cryoturbation in Mackenzie area. Black spruce forests are typically grown on the shoulder of of mounds. Tree rings could record 200 year-history of tilting induced by hummock formation. Black spruce trees on shallow permafrost are considered to grow on low supply of N by taking up amino acids. Here, we report new finding on N uptake by black spruce trees. We compared N acquisition strategies of black spruce trees growing on shallow permafrost table and those on deep permafrost table.

Materials and methods: We compared two contrasting sites of black spruce forest in Northwest Territories, Canada; black spruce forest on clayey soil derived from glacial till underlying shallow permafrost layer (20 to 30 cm; CLY) and black spruce forest on glaciofluvial sands underlying deeper permafrost layer (70 cm; SND). To reconstruct the history of soil hummock formation, tree ring widths were measured year by year. The magnitude of tree tilting was calculated by the maximum tree ring width dividing by the minimum tree ring width. Regarding soil N dynamics, the concentrations of organic N, urea, and inorganic N in soil solution extracted by centrifugation were measured. Root uptake of dual-labeled (^{13}C, ^{15}N) glutamic acid, dual-labeled (^{13}C, ^{15}N) urea, ^{15}N-labeled ammonium, and ^{15}N-labeled nitrate was measured 24 h after spike of mixture solution.

Results and Discussion: Hummocky soil structure is greater in the CLY site than in the SND site. Tree ring analyses suggested that trees started tilting in response to shallow permafrost table in the CLY site. Earth hummocks could be formed over 100 years and hummock formation is being activated in recent decades. Soil solution contained the high concentrations of amino acids in both the CLY and SND sites. The concentrations of inorganic N were consistently low in the CLY site, whereas they were high in the SND site. Urea was present in the deeper soil horizons of the CLY site, but no urea was found in the organic horizons of the CLY site and the soil profile of the SND site. Root assimilation of glutamic acid ^{15}N suggested that black spruce could utilize amino acid-N in the CLY site. However, $^{13}C/^{15}N$ ratios of roots are lower than those of glutamic acid and close to urea$^{13}C/^{15}N$ ratio. This is consistent with the high accumulation of urea in the deeper soil horizons immediately above the permafrost table. These data suggested that spruce tree roots could take up urea in the CLY site. This was also supported by assimilation of urea-^{13}C and -^{15}N. In the SND site, tree roots preferentially absorb inorganic N (ammonium and nitrate). The flooding and cold conditions on shallow permafrost table can retard mineralization of amino acids to inorganic N. Black spruce tree roots can develop strategies

Conclusion: Tree ring analyses suggested that earth hummocks could be formed over 100 years and that hummock formation is being activated in recent decades. Black spruce trees on shallow permafrost soil have unique strategies to utilize urea in the deeper soil horizons of earth hummocks. Since this process is highly dependent on depth of permafrost table, niche narrowing of black spruce trees can be predicted as one of potential impacts of future climate change.