Applying ATR-FTIR spectroscopy to Characterize and Discriminate Tundra Plant Leaves

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The chemical property of leaves is an important aspect of functional trait of tundra plants as it represents the biochemical features explaining not only their response to environmental change but also their effects on ecosystem function. Understanding chemical properties of leaves is thus crucial for the understanding of arctic terrestrial ecosystems, where plant growth is strongly limited by such environmental factors as low temperature, low moisture, low nutrient availability, and a short growing season. The attenuated total reflection Fourier transform infrared (ATR-FTIR) spectroscopy is a powerful tool of investigating functional traits of plants, but its applicability to tundra plant leaves was yet to be addressed.

The purpose of the present study was to apply the ATR-FTIR measurement to characterize biochemical fingerprint of tundra plant leaves and to discriminate it between plant species. We used a total of 50 samples each for live and dead leaves from 14 plant species of shrubs, forbs, graminoids, and mosses collected in the proglacial field of the southern front of Arklio Glacier in the Kreiger Mountains near Oobloyah Bay, Ellesmere Island, Nunavut, Canada (Osono et al., 2006). The ATR-FTIR measurement allows complex assemblages of organic constituents to be displayed as distinctive spectral features in the mid infrared range (4000-400 cm-1). Fundamental vibration modes of specific functional groups yield characteristic spectral absorption features that provide comprehensive biochemical fingerprint of various organic compounds in leaf samples (Silverstein et al., 2012).

The ATR-FTIR spectra in the fingerprint region of live and dead leaves from 14 tundra plant species of shrubs, forbs, graminoids, and mosses showed a variability in overall appearance between plant species and a degree of similarity between live and dead leaves of the same plant species. At least 16 peaks were obvious in the spectra of live and dead leaves of 14 plant species, 5-9 peaks per plant species. Of thse, four highest peaks were found between 1575 and 1637 cm^{-1}, 1406 and 1452 cm^{-1}, 1313 and 1325 cm^{-1}, and 1022 and 1058 cm^{-1} and are attributed to chemical features of lignin, cellulose, and/or oxalate. The overall spectra in the fingerprint region were significantly different between plant species both for live and dead leaves [one-way permutational multivariate analysis of variance (PERMANOVA), d.f. =13, $P<0.001$].

Cluster and principal component analyses showed that leaves of Oxyria digyna and other forbs had distinctive spectral characteristics attributable to the content of oxalate and other putative compounds. The spectra of shrubs had greater values of relative height at 1575 and 1637 cm^{-1} and 1406 and 1452 cm^{-1} than those of graminoids and mosses. This difference is due to the fact that contents of lignin relative to cellulose were generally greater in shrubs than in graminoids and mosses.

In conclusion, the ATR-FTIR spectroscopy can detect a suite of organic components that characterize live and dead leaves of tundra plant species. Such spectral measurements can be used as a tool to describe functional traits of plants (Mori et al., 2017). The ATR-FTIR measurement will also be potentially useful in documenting the process of microbial decomposition and soil formation in arctic tundra. Future studies using the ATR-FTIR spectroscopy are needed for tundra plants in polar regions to characterize the process of decomposition of plant leaves and depolymerization of organic constituents.

References

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