Field-based detection of Solar-Induced Chlorophyll Fluorescence for remote-sensing of the photosynthetic activity in winter wheat with Nitrogen addition treatments in Hokkaido

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Solar Induced Chlorophyll Fluorescence (SIF), which has been recognized as the emerging remote sensing proxy of photosynthetic capacity, was measured at the canopy of winter wheat field for assessing the plant growth. SIF is thought to be emitted to incoming solar radiation, and expressing the amount of energy transportation of photochemical system in diurnal to seasonal cycles, and could be applied to assess the Gross Primary Production (GPP) and photosynthetic stress on wheat canopy. Thus, SIF seems to have the advantage in detection of the growth status more sensitively, compared to the other pigment-content indices, which respond insensitively to shorter time scale cycle. However, as we know there was no study focusing SIF signal among N fertilize stages and apply it to the crop growth prediction. We developed the continuous SIF measurement system with high resolution spectrometer, and examined the relationships of SIF to (i) photosynthesis estimated by ecophysiological model, (ii) leaf-level chlorophyll content, photosynthetic capacities, and (iii) plants height in 3-levels Nitrogen fertilizer treatments in a winter wheat field, to elucidate the potential of SIF to detect the crop growth. High resolution spectrometer (HR4000, Ocean Optics, Dunedin, FL, USA; range: 629-824 nm, sampling spectral interval: 0.060 nm, spectral resolution: 0.12 nm) was installed to measure spectral irradiances from sun and vegetation during June-July in 2018, and April-July in 2019 at a wheat field in Hokkaido Agricultural Research Center (HARC), Sapporo, Hokkaido. Spectrometer was connected to one fibre targeting sun and six optical fibres targeting on vegetation at three different N fertilized plots with 2 replications from 3 m height at 45-degree tilt. SIF was retrieved using spectral fitting method for O_2-A absorption band (759-767nm). Vegetation indices including normalized difference vegetation index (NDVI) and photochemical reflectance index (PRI) was also calculated from spectral data. We also observed leaf-level photosynthesis capacities (Vcmax, Jmax) by A-Ci curves measured by Li-6400 (Li-cor, Lincoln, NE, USA), fluorescence with pulse amplitude modulation Mini-PAM (Waltz, Effeltrich, Germany), relative chlorophyll content by SPAD (SPAD 502 plus, Konica-Minolta, Tokyo, Japan) and plants height by ruler. Meteorological data including air temperature and humidity is provided by HARC. We presented that SIF varied daily and seasonally, and those patterns differed among N fertilising stages, and related with factors of leaf photosynthetic activity, modelled CO_2 assimilation ratios. This study could provide insight not only for ecophysiological modelling with SIF but also for developing farming tools (*e.g.* smart-agriculture and ICT) for efficient wheat production.

Keywords: Remote sensing, SIF, NDVI, Wheat crop field, Seasonal variation, Photosynthesis