From Spectral Screening to Robotic Multimodal Imaging: Towards Nitrogen Assessment in Field-Grown Broccoli

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Efficient nitrogen management in vegetable production requires spatially resolved assessment of plant N status to improve N efficiency, promote uniform crop growth, and enable sycnhronized harvesting. This study evaluates photonic sensing approaches for N assessment in broccoli (*Brassica oleracea* var. *italica*) and their suitability for autonomous robotic imaging. Broccoli cv. 'McLaren' was grown in field and greenhouse trials under different N supplies. A randomized block design with four replicates included 40 kg N ha^{-1} as the soil N baseline and 70 and 100 kg N ha^{-1} treatments. Plant N content was determined using the Dumas method and N uptake was subsequently calculated. Spectral measurements included FieldSpec (Yara), Multiplex (Force-A), Mako G-419B (Allied Vision), and a fluorescence camera based on a Raspberry Pi HQ Camera. Measurements were acquired in weeks 6 and 7 after planting, alongside tests of measurement effects related to plant development and leaf contamination by splash water and soil particles.

Higher VIS and lower NIR reflectance, increased phenol-related responses, and decreased chlorophyll fluorescence were associated with variation in N uptake. For most sensors, correlations between spectral indices and plant N uptake were stronger at later measurement dates, with the strongest relationships observed in week 7. Leaf surface water increased reflectance across the VIS region, while soil particles also altered the measured spectra. These effects highlight the importance of measurement timing and robust data-quality validation for field deployment.

Based on the spectral evaluation, a multimodal robotic imaging platform is being developed for autonomous on-farm data acquisition. Spectral processing includes correction of optical effects such as vignetting and dark current before calculation of spectral indices. The platform combines a stereo camera to capture plant morphology and development with two spectral cameras and active illumination, complemented by RTK positioning, on-board AI computing, and automated plant detection and triggering. This setup provides the basis for standardized, georeferenced multimodal N assessment in field-grown broccoli. Ongoing work focuses on sensor calibration, data-processing pipelines, and validation across locations, cultivars, and repeated trials, with main data acquisition planned for 2027.