Development of Multispectral Image Sensor through Band Selection for Detecting Bacterial Pustule of Soybean Plant based on Hyperspectral Image

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Soybean (Glycine max (L.) Merrill) is a globally important crop for human nutrition and animal feed. Recently, soybean diseases such as bacterial pustule have been increasing depending on extreme weather changes, and those are led to a decline in soybean production. It requires a time-consuming and labor-intensive process to identify this disease at an early stage. Therefore,This study aims to present bands for developing a multispectral image sensor that is advantageous for detecting soybean bacterial pustules in agricultural fields through hyperspectral image data analysis of bacterial pustule disease not inoculated group (controlled) and inoculated group (treated).

The experiment for the Daechan cultivar was conducted in a glass greenhouse at the National Institute of Crop Science. The seeds were sown on April 18, 2022, with two groups with four repetitions, and the inoculation of bacterial pustule disease was performed on May 16. The expert's visual inspection was operated daily after inoculation, and the bacterial pustule disease was observed on May 24 and May 25. Hyperspectral images (FX10, Specim Spectral imaging Ltd., Finland) were daily acquired from May 16 to June 3, at 11:00 am, and were processed using ENVI 5.3(Exelis Visual Information Solution Inc., USA). The reflectance was smoothed by the Gaussian filter to reduce the noise of images and merged to 10nm of FWHM(Full Width at Half Maximum). T-test was applied to identify the wavelengths with the significant difference between controlled and treated plants, and VIs(Vegetation Indices) were calculated using those wavelengths. Classification models such as PLS-DA(Partial Least Squares Discriminant Analysis), SVM(Support Vector Machine), and RF(Random Forest) were developed with SHAP(SHapley Additive exPlanations) feature selection to classify controlled and treated plants by Finepro(Hortizen Co Ltd., Republic of Korea). The performance of models were compared with the confusion matrix, OA(Overall Accuracy), and KC(Kappa Coefficient).

When the smoothed average of reflectance was compared, the reflectance of controlled plants was almost higher than that of the treated plants. In the t-test, 420nm, 540nm, 600nm, 700nm, 780nm, and 940nm were selected as the wavelength with significant differences between the controlled and treated plants with the lowest p-value in each wavelength ranges, such as blue, green, red, red-edge, NIR1, and NIR2, respectively. Using vegetation indices calculated from those selected bands in each range, the RF model with 5 VIs (BNDVI and YVI with NIR2, Green/Red, NIR1/Blue, NIR2/Blue) based on SHAP feature selection showed the best performance with an OA of 0.888 and a KC of 0.774. The number of VIs for SHAP feature selection was determined depending on the performance of models and the confusion matrix.

When the data before diagnosing bacterial pustule symptoms (May 16~May 24, 48 samples) was applied to the RF model with these selected VIs and parameters, the prediction performance for classification was 0.772 for OA and 0.552 for KC. This result indicates the potential of predicting disease before symptoms show using hyperspectral imaging and machine learning. It is necessary to validate the model using data from multiple years and actual field observations to apply it practically for real-time field monitoring.

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