DISCRIMINATING WHEAT APHID DAMAGE LEVEL USING SPECTRAL CORRELATION SIMULATING ANALYSIS

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ABSTRACT

Wheat aphid, Sitobion avenae F. is main aphid species infesting winter wheat in the filling stage in Northwest China, and it has severe impact on both wheat yield and quality. The study acquired hyperspectral data by ASD FieldSpec Pro spectrometer at the canopy level and aphid damage levels of samples in the filling stage of winter wheat. The spectral characteristics of wheat uninfected by aphid and healthy wheat were analyzed, then the correlation simulating analysis model (CSAM) which was established by a 2-dimensional coordinate system with average spectral of healthy wheat samples called also base spectrum as abscissa axis and the spectral of other samples as vertical axis respectively is developed and tried to monitor the aphid damage levels. It is concluded that the fitting curves obtained by the reflectance of samples relative to healthy wheat samples are near to straight line in the range from 400nm to 1000nm (R^2>0.99), and the slopes of fitting lines decrease as aphid damage levels become serious. Moreover, the most sensitive band regions were selected out. The result shows that the correlation between the slopes of fitting line and aphid damage levels is the highest in the range from 400 nm to 810 nm (R^2=0.89). Therefore, the CSAM can be sued to discriminate the aphid damage levels in the filling stage of winter wheat.

Index Terms—Spectral difference analysis; Visible and near-infrared spectra; Wheat aphid; Correlation simulating analysis model (CSAM)

1. INTRODUCTION

Wheat aphid, Sitobion avenae (*Fabricius*), is one of the most destructive pests in agricultural systems, especially in the regions of temperate climate in the northern and southern hemispheres and occurs annually in the wheat planting area of China. Aphid feed on wheat plants and injects saliva that contains plant toxins, which results in significant yield loss [1, 2]. It is important to monitor aphid infestation at critical junctures of crop growth and obtain spatial distribution information on aphid infestation within a particular field for site-specific management and judicious application of pesticides. The common and conventional ways to obtain information of density infestation in the field is by manual field scouting, which has been shown to be expensive, time-consuming, and difficult for large farms[3]. Detecting wheat aphid damage levels via spectral measurement and analysis is a superior alternative to a traditional method in obtaining the spatial distribution information of aphid.

There has been some progress made in detecting aphid infestation density at wheat canopy level using hyperspectral remote sensing. Yang et al.(2005) found that the band centered at 694nm and the vegetation indices derived from bands centered at 800 and 694nm were the most sensitive to greenbug-damaged wheat[4]. Mirik et al. (2006) found that damage sensitive spectral index1(DSSI1), damage sensitive spectral index2 (DSSI2) and simple ratio (SR) were related to damage by greenbug, and then developed an aphid index（AI）which had the strongest relationships with greenbug density[5,6]. Yang et al. (2009) suggested that ratio-based vegetation indices (based on 800/450 nm and 950/450 nm) were useful in differentiating the stress caused by Russian wheat aphid and greenbug in wheat[7]. These findings suggest that remote sensing using spectral reflectance and indices can be an effective technique for non-destructively detecting plants stressed by Russian wheat aphid and greenbug.

The study aimed to identify spectral characteristics of wheat induced by aphid infestation at canopy scale and then discriminate from aphid damage levels by the correlation simulating analysis model (CSAM) based on the visible and near-infrared reflectance in the filling stage of wheat.

2. MATERIALS AND METHODS

2.1 Study site and materials

The field experiment plot is located at Xiaotangshan Precision Agriculture Experiment Base, in Changping District, Beijing (40º10.6'N, 116º26.3'E). The experimental field is about 250 m in length and 80 m in width. The winter wheat of study area was planted approximately on October 3, 2009, and harvested on June 25, 2010. Field inventory was conducted on June 7, 2010 when wheat was in the filling stage. 25 ground investigations including different aphid damage levels were collected. There are six levels depending on aphid density and Aphid damage levels were assessed according to the investigation rule [8].

2.2 Canopy spectral measurements

In each investigation spot, an area of $1m^2$ was selected for canopy spectral reflectance measurement using an ASD FieldSpec Pro spectrometerfitted with a 25°field of view fiber optic adaptor which operated in the 350-2500nm spectral range. Reflectance measurements were taken by averaging 10 replicate scans at optimized integration time, with a dark current correction at each spectral measurement. Calibration panel reflectance measurements were taken before and after canopy spectral measurement.

2.3 Correlation simulating analysis model

It is reported that correlation simulating analysis model (CSAM) is an effective discrimination and classification method and can remove the background noises [9]. The CSAM can be expressed as:

$$R(\lambda_i) = F\,[R_0(\lambda_i)]$$

where R and F were the spectrum curves, i is the waveband number, R_0 is the spectral intension of abscissa, F is the function of scatter plot. The scatter plot is called as spectral correlation diagram. $R_0(\lambda_i)$ as abscissa is called as basic spectrum, and in the study, the average spectral reflectance of healthy wheat is as basic spectrum, and the range from 400 nm to 1000 nm is selected to do correlation simulating analysis.

3. RESULTS

3.1 Response of wheat canopy reflectance to aphid damage degree

By comparing the canopy spectral differences between aphid-infested and healthy wheat, it indicated that canopy reflectance gradually decreased in the range from 350 nm to 1750 nm, especially in the near infrared region (Fig.1). The result was not consistent with previous researches [10] that the stressed wheat had higher reflectance in visible bands than the healthy wheat because the photoactive pigments (chlorophylls, anthocyanins, carotenoids) were destroyed. The reason was that aphid occurred in the filling stage of wheat, and the honeydew excreted by aphid absorbed dust from surrounding environment and then mildewed wheat leaf, so the leaf got dirty and little black, which made the absorption in the visible bands became strong but not weak.

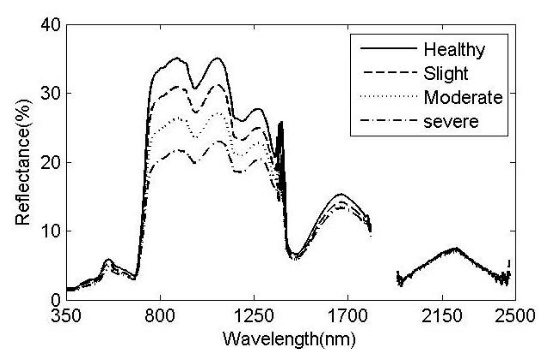

Fig.1 The spectral reflectance of healthy wheat and wheat

infested by various aphid damage levels. (Healthy: the average spectra of healthy wheat samples; Slight: the average spectra of aphid damage level 1 and 2; Moderate: the average spectra of aphid damage level 3 and 4; Severe: the average spectra of aphid damage level 5 and 6)

3.2 Correlation simulating analysis of wheat infested by aphid

Correlation simulating analysis is performed with the average spectrum of healthy wheat as basic spectrum and the spectrum of investigation plot as vertical axis. Fig.1 is the correlation scatter plot. It is concluded that the fitting line of scatter plot between the reflectance of samples and basic spectrum are near to straight line (R^2>0.99), and the slopes of fitting lines are decreasing as aphid damage is becoming serious.

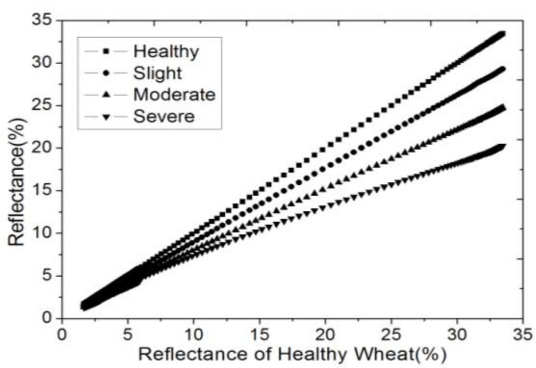

Fig. 2 The scatter plot between the canopy reflectance of wheat infested by aphid and reflectance of healthy wheat (Healthy: 0 Level; Slight: average reflectance of aphid damage level 1 and level 2; Moderate: average reflectance of aphid damage level 3 and level 4; Severe: average reflectance of aphid damage level 5 and level 6).

3.3 Selecting the best band region and discriminating aphid damage level

121 slopes of fitting lines are obtained every 5nm beginning at 400 nm and ending at 1000 nm every sample. Fig. 3 is the determination coefficients between the slopes of fitting line and aphid damage levels in the different band regions. It is showed that the determination coefficients (R^2) greatly depended on the band region, and determination coefficients between the slopes of fitting line and aphid damage levels is the highest (R^2=0.89)in the region from 400nm to 810 nm. Therefore, the model can be established between aphid damage levels and the slopes of fitting line of scatter between canopy reflectance of every sample and the average reflectance of healthy wheat samples in the region from 400nm to 810nm (Fig. 4).

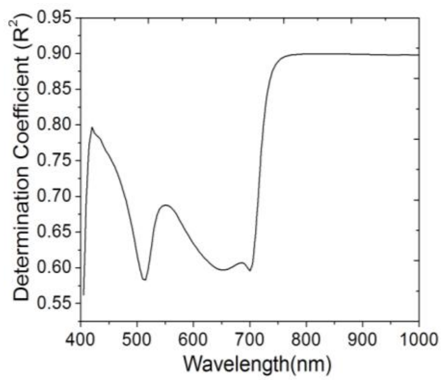

Fig.3 Determination coefficients between the slopes of fitting line and aphid damage levels in the different band regions

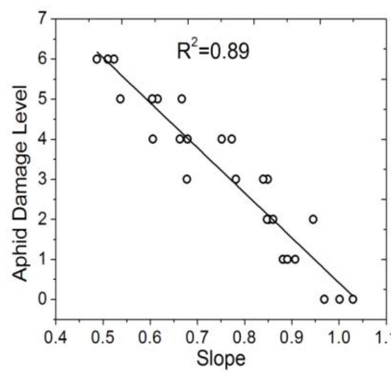

Fig. 4 The correlation between slopes of fitting line and aphid damage levels

4. CONCLUSION AND DISCUSSION

Hyperspectral remote sensing has undertaken rapid development over the past two decades and there is a trend towards the usage of hyperspectral images in the remote sensing applications for precision agriculture [5]. The study analyzed the spectral characteristics of wheat infested by aphid and tried to discriminate the aphid damage level by spectral correlation simulating analysis. The correlation scatter plot between the reflectance of samples and the reflectance of healthy wheat are obtained, and the result shows that the fitting line of scatter plot are near to straight line (R^2>0.99), and the slopes of fitting lines are decreasing with aphid damage levels becoming serious. Moreover, in the range from 400 to 810 nm, the determination coefficient between the slopes of fitting line and aphid damage levels is the highest (R^2=0.89). Consequently, spectral correlation simulating analysis is an effective method for discriminating the aphid damage level and the slopes of fitting lines could retrieve the aphid damage levels in the filling stage of wheat.

In comparison with other monitoring aphid damage level methods, spectral correlation simulating analysis can obtain better discrimination result using only limited visible and near-infrared reflectance spectroscopy bands (400-810 nm).

Crop growth is very dynamic, so monitoring the condition of agricultural corps is a complex issue. Therefore, it was possible that wheat damage symptoms caused by aphids and response of canopy reflectance was different in different growth stages. In the study, it was lower for the reflectance of wheat infested by aphid than that of healthy wheat in the filling stage of wheat because of honeydew excreted by aphid was not consistent with previous studies in the early detection of aphid infestation. So, whether the model could retrieve aphid damage levels in other growth stages of wheat should be verified by the further experiments.

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