Use of vegetation indices in monitoring sugarcane white leaf disease symptoms in sugarcane field using multispectral UAV aerial imagery

P Sanseechan¹, K Saengprachathanarug¹², J Posom¹², S Wompichet¹, C Chea¹ and M Wongphati³

¹ Curriculum of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen, Thailand
² Applied Engineering for Important Crops of the North East Research Group, Khon Kaen University, Thailand
³ HG Robotics Company Limited, Bangkok, Thailand

E-mail: khwantri@kku.ac.th

Abstract. Currently, controlling or identifying of the sugarcane white leaf disease infection is not possible since its symptom need to be observed by human walking throughout fields. Therefore, this research aims to study the ability of vegetation indices to detect white leaf disease infected sugarcane with images taken by multispectral camera mounted on Unmanned Aerial Vehicle. Three sub-images infected with white leaf symptom and 3 other sub-images of normal green leaf were selected for this study. The reflectance values of 6 chosen sub-images were used to calculate 18 vegetation indices, and then these indices were used to compute the difference percentage of vegetation (green versus white) in order to find vegetation indices that are the most sensitive to white leaf symptoms. The results show that vegetation indices that have NIR and Red edge band in their formula (14 vegetation indices) have difference percentage in the range of 14.66 - 45.10, with NDREI, GNDVI yielding the highest difference percentage (44.05 - 45.10%), and vegetation indices that have only visible bands in their formula (4 vegetation indices) have the difference percentage from 14.96 - 26.04%, with GI and NRI resulting in the highest difference percentage 24.04% and 26.04%, respectively.

1. Introduction
Sugarcane white leaf disease caused by PHYTOPLASMA plasma is transmitted by leafhoppers. In year 2011/12, there were reports about outbreak of white leaf disease over 32,000 hectare of sugarcane field causing damage worth at least 2,000 million baht and the outbreak of the disease has been increasing resulting in severe damage to the sugar cane industry [1].

In general, sugarcane infected with white leaf disease might either show or not show symptoms of the disease. So, the infected sugarcane stalks without showing symptoms, unintentionally used for next growing season, would lead to disease transmission. Hanboonsong has used Nested PCR test to detect white leaf disease in sugarcane billets, however, this method consumed long time and need to pay high expense [2]. On the other hand, there is still no treatment for this disease, so growers use conventional methods by going into fields to observe infected areas, and then eradicate infected sugarcanes by burning. However, this method needs a lot of time to observe the whole fields for spotting the
locations of infected area. Thus, if we can quickly identify locations of infested area in fields, then we can control or inhibit the infestation on time.

The use of satellite imagery can solve problem of large size of field since it can capture huge area, but its information is not real-time and flexible. So, it is not very suitable for use in the detection of disease. In response to rapidity and flexibility, Unmanned Aerial Vehicle (UAV) has become a popular platform to facilitate image acquisition for precision agriculture application.

Recently, there have been many investigations about using UAV as a platform to monitor plant diseases such as detection of downy mildew of opium poppy [3], symptoms of Flavescence Doree in Grape leaf [4], and symptoms of yellow rust disease of wheat [5]. These researches conducted multispectral imagery, coupled with vegetation index, to detect the symptoms of the disease.

From review of related researches as mentioned above, it can be conclude that vegetation indices can interpret vigor status of crops. Therefore, the purpose of this research is to study the capability of vegetation indices in identification of sugarcane white leaf symptoms in the field by multispectral camera mounted on UAV.

2. Materials and Methods

2.1. Study sample
The sugarcane samples, Khon Kaen 3 variety with aging of 5 months after planting, were chosen from field locates in Nam Phong District Nam Phong province, Thailand. Three areas were selected in this field which 1\textsuperscript{st} area (G1) didn’t have white leaf symptom, 2\textsuperscript{nd} and 3\textsuperscript{rd} areas (W1 and W2) had white leaf symptoms. Each area had dimension of 9 m. x 10 m. In area W1 and W2, 3 sub-images with dimension 4 x 4 pixels from each area were randomly selected while 6 sub-images with the same dimension were chosen from G1 area (figure 1). Three repetitions were performed for the selection. Therefore, 12 sub-images were obtained for one dataset.

![Figure 1. Example of cane used in the study.](image)

2.2. Information about the photos
The sugarcane samples, Khon Kaen 3 variety with aging of 5 months after planting, were chosen from field locates in Nam Phong District Nam Phong province, Thailand. Three areas were selected in this field which 1\textsuperscript{st} area (G1) didn’t have white leaf symptom, 2\textsuperscript{nd} and 3\textsuperscript{rd} areas (W1 and W2) had white leaf symptoms. Each area had dimension of 9 m. x 10 m. In area W1 and W2, 3 sub-images with dimension 4 x 4 pixels from each area were randomly selected while 6 sub-images with the same dimension were chosen from G1 area (figure 1). Three repetitions were performed for the selection. Therefore, 12 sub-images were obtained for one data set.
2.2.1. Unmanned aerial vehicle (UAV). This experiment used UAV with 6 rotors, VESPA HEX 650 (HG Robotic company, Thailand) (figure 2). Its weight is 4.5 kg and summary of specification is shown in table 1.

![Figure 2. UAV used in the study.](image)

| Type               | Specification                  |
|--------------------|--------------------------------|
| Name               | VESPA HEX 650                  |
| Number of rotors   | 6                              |
| Takeoff weight     | 4.5 kg                         |
| Communication distance | 1200 m                       |
| GPS                | Mini Ublox NEO-M8N             |
| Battery            | Lipo battery, 10000mAh, 22.2 V |
| Operation capacity | 10-15 minutes                  |

2.2.2. Multispectral camera. Multispectral camera used in this study (Micasense Red edge) has 5 bands consisting of blue, green, red, NIR, and Red edge band. Its weight was 150 g and it provided image with dimension 1280 × 960 pixels.

2.2.3. Image acquisition. Before flight mission, flight planning was created in flight planning program (HG Robotic company, Thailand) (figure 3). Flight altitude was set at 44 meters above mean sea level (MASL), providing images with a Ground Sampling Distance (GSD) of 3 cm/pixel, speeds of 5 m/s, frontal and side overlaps of 80% and 60%, respectively. The flight time was at around 11:00 am to 13:00 pm. In addition, 6 ground control panels (GCP) were installed around field.

![Figure 3. Flight planning program.](image)
2.3. Calculation of difference percentage between white leaf area and green leaf area in images acquisition.

Acquired images were transformed into reflectance maps in Pix4D mapper version 4.0 (Pix4D, Switzerland). After that, 5 reflectance maps (Blue, Green, Red, NIR, Red edge) were viewed in Photoshop to identify pixel location of selected areas and chosen sub-images. Then, 18 vegetation indices value of all sub-images were computed in Matlab program 2018a.

For each vegetation index type, maximum (Max) and minimum (Min) value were selected among total 12 sub-images, while mean of green leaf (MG) was calculated from VIs value of 6 sub-images of green leaf area (G1) and mean of white leaf (MW) was calculated from VIs values of 6 sub-images of white leaf area (W1 and W2) (figure 4). Finally, difference percentage of each vegetation index (table 2.) can be calculated according to equation 1.

\[
DPWG (\%) = \left( \frac{MG - MW}{Max - Min} \right) \times 100
\]  

Figure 4. Calculation of difference percentage between white leaf area and green leaf area in images acquired (DPWG).
Table 2. Spectral bands and VIs adopted in this study [5].

| Name                                               | Abbrev.   | Formula                                      |
|-----------------------------------------------------|-----------|----------------------------------------------|
| NIR and Red edge group                               |           |                                              |
| Normalized Difference Red edge Index                | NDREI     | (NIR\(^a\) - RE\(^b\)) / (NIR + RE)         |
| Green NDVI                                          | GNDVI     | (NIR - G\(^c\)) / (NIR + G)                 |
| Ratio Vegetation Index                               | RVI       | NIR/R\(^d\)                                 |
| Simplified Canopy Chlorophyll Content Index          | SCCCI     | NDREI/NIR + G                              |
| Normalized Difference Vegetation Index              | NDVI      | (NIR - R) / (NIR + R)                       |
| Optimized Soil Adjusted Vegetation Index            | OSAVI     | 1.16(NIR - R) / (NIR + R + 0.16)            |
| Triangular Vegetation Index                         | TVI       | 0.5[120(NIR - G\(^2\)) - 200(NIR - G)]     |
| Soil Adjusted Vegetation Index                      | SAVI      | 1.5(NIR - R) / (NIR + R + 0.5)               |
| Enhanced Vegetation Index                           | EVI       | 2.5(NIR - R) / (NIR + 6R - 7.5B + 1)        |
| Anthocyanin Reflectance Index                       | ARI       | (1/G) / (1/RE)                              |
| Transformed Chlorophyll ARI                         | TCARI     | 3[(RE - R) - 0.2*(RE - G)(RE/R)]            |
| Chlorophyll Vegetation Index                        | CVI       | (NIR\(^*\)R) / (G\(^2\))                   |
| Chlorophyll Index-Green                             | CIG       | NIR / (G - 1)                               |
| Chlorophyll Index-Red edge                         | CIRE      | NIR / (RE - 1)                              |
| RGB group                                           |           |                                              |
| Greenness Index                                     | GI        | G/R                                         |
| Nitrogen Reflectance Index                          | NRI       | (G - R) / (G + R)                           |
| Green Leaf Index                                    | GLI       | (2G - R - B) / (2G + R + B)                 |
| Triangular Greenness Index                          | TGI       | -0.5 * 190 * (R - G) - (120) * (R - B)      |

\(^a\) Near-infrared band
\(^b\) Red Edge band
\(^c\) Green band
\(^d\) Red band
\(^e\) Blue band

2.4. Analysis of variance (ANOVA)
In order to compare the performance of vegetation indices which have NIR or Red edge band to vegetation indices which consist of visible band (RGB), the two vegetation indices which have the highest difference percentage from these two groups were analyzed by ANOVA.

2.5. Analysis of variance (ANOVA)
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3. Results and Discussion

3.1. Difference percentage between white leaf area and green leaf area derived from images.
According to figure 5, illustrated the results of vegetation indices of the data set 1, including maximum, minimum, means of green leaves and white leaves. The high difference between green leaves and white leaves were found in RVI, TVI, ARI and CVI indices, which consisting of NIR and Red edge band. Meanwhile the group consisting of RGB bands found that GI and TGI had high differences between green leaves and white leaves. The result was the same as data sets 2 and 3.
Figure 5. Summary of Maximum, Minimum, Mean of Green leaf, and Mean of white leaf of 18 vegetation indices in data set 1.

Table 3 shows the vegetation indices group consisting of NIR and Red edge band. The range of difference percentage between white leaf area and green leaf area was approximately 14.66% - 45.10%. Two highest differences were found in NDREI and GNDVI, showing 45.10% and 44.05%, respectively. Meanwhile, vegetation indices group of RGB bands (including 4 vegetation indices) were ranged between 14.96% and 26.04%, which GI and NRI had the highest difference range of 26.04% and 24.04% orderly, as shown in table 4.

### Table 3. Difference percentage between white leaf area and green leaf area in acquired images (NIR and Red edge band).

| VI      | Data set 1 (%) | Data set 2 (%) | Data set 3 (%) | Mean (%) |
|---------|----------------|----------------|----------------|----------|
| NDREI   | 49.88          | 46.37          | 39.05          | 45.10    |
| GNDVI   | 49.37          | 44.68          | 38.09          | 44.05    |
| RVI     | 53.62          | 40.65          | 30.08          | 41.45    |
| SCCCI   | 34.24          | 40.06          | 38.53          | 37.61    |
| NDVI    | 45.09          | 41.09          | 26.46          | 37.55    |
| OSAVI   | 45.42          | 40.99          | 22.50          | 36.30    |
| TVI     | 46.68          | 41.29          | 20.15          | 36.04    |
| SAVI    | 45.06          | 40.51          | 18.82          | 34.80    |
| EVI     | 45.83          | 38.18          | 15.92          | 33.31    |
| ARI     | 16.97          | 29.47          | 5.80           | 24.04    |
| TCAI    | 2.72           | 28.43          | 27.93          | 19.70    |
| CVI     | 2.04           | 23.70          | 30.34          | 18.69    |
| CI    | 27.55          | 16.67          | 6.42           | 16.88    |
| CIRE    | 23.44          | 10.61          | 9.92           | 14.66    |

### Table 4. Difference percentage between white leaf area and green leaf area in acquired images. (RGB band).

| VI      | Data set 1 (%) | Data set 2 (%) | Data set 3 (%) | Mean (%) |
|---------|----------------|----------------|----------------|----------|
| GI      | 42.81          | 29.52          | 5.80           | 26.04    |
| NRI     | 36.90          | 28.42          | 6.79           | 24.04    |
| GLI     | 31.86          | 26.93          | 3.19           | 20.66    |
| TGI     | 31.02          | 12.92          | 0.94           | 14.96    |
### Table 5. Difference percentage than top VI from NIR, Red edge group and RGB group.

| Band     | NIR and Red edge | RGB  |
|----------|------------------|------|
| VI       | NDREI (%)        | GNDVI (%) | GI (%) | NRI (%) |
| Data set 1 | 49.88           | 49.37  | 42.81  | 36.90  |
| Data set 2 | 46.37           | 44.68  | 29.52  | 28.42  |
| Data set 3 | 39.05           | 38.09  | 5.80   | 6.79   |

According to table 5, the top two vegetation indices (NDREI, GNDVI) from NIR or Red edge group have higher difference percentage than top two vegetation indices (GI, NRI) from RGB group. However, vegetation indices from RGB group can be obtained by using low-cost RGB digital camera and less complicated process. Additionally, if advance images processing is applied to digital imagery, it might improve white leaf detection ability of vegetation indices solely computed from visible bands.

#### 3.2. The results of ANOVA test.

Table 6 shows the results of comparison for the difference percentage of vegetation indices group that use NIR and Red edge band and vegetation indices group that use RGB band by One-way ANOVA.

### Table 6. Results of ANOVA for vegetation indices.

| SOV    | SS       | df | MS    | F      | P-value | F crit |
|--------|----------|----|-------|--------|---------|--------|
| Between | 1144.44  | 1  | 1144.43 | 8.68  | 0.02 | 4.97 |
| Within  | 1318.21  | 10 | 131.82 |       |       |       |
| Total   | 2462.64  | 11 |        |        |       |       |

According to table 6, it appears that there was statistically significant difference (p-value = 0.05).

#### 4. Conclusions

This study shows that vegetation indices acquired from multispectral images based on UAV could be used to detect white leaf disease of sugarcane in the field. Even though vegetation indices with NIR and Red edge band (NDREI and GNDVI) provide the best detection, vegetation indices solely computed from RGB band (GI and NRI) also have potential in detection of white leaf symptoms with acceptable quality and low-cost. However, various sources of samples and experimental fields such as sugarcane varieties, the age of the sugarcane at white leaf symptoms and type of soil are needed for further study.

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