A Rice Leaf Color Chart using Low-Cost Visible Spectro Sensor

Tran Khac Duy, Tran Thi Ngoc Huyen, Nguyen Minh Trang, Luong Vinh Quoc Danh, Anh Dinh

ABSTRACT---Rice yield is directly affected by the plant macronutrients, mainly Nitrogen (N) status. During growing cycle, farmers must determine when to apply N fertilizer as the nitrogen deficiency leads to lower yield and economic lost. Chlorophyll meter and leaf color chart (LCC) have been used for years to find the correlation between the rice chlorophyll and its nitrogen use, hence the demand of N in the field during growing cycle. LCC is more preferred as it is the least expensive but the technique is not accurate and the readings are not consistent. This work develops a very simple sensor device which uses extremely low-cost, off-the-shelf optical components to replace the rice leaf color chart. The heart of the device is the AS7262 6-Channel Visible Spectral ID device made by AMS. The sensor prototype was built and tested. Preliminary results show a promising device which is very low cost, simple, low maintenance, and easy to use in the field to support rice growers to determine the need for nitrogen in the growing cycle.

Keywords- rice leaf nitrogen, leaf color chart, visible spectrometer, low-cost sensor

I. INTRODUCTION

Nitrogen (N) fertilizer is important in rice production. Apply N fertilizer several times during the growing season to ensure that the crop's nitrogen need is supplied, particularly at critical growth stages [1]. The Leaf Color Chart (LCC) developed by the International Rice Research Institute (IRRI) is normally used by the farmers to determine the N fertilizer need of rice crops. LCC has four (or six) green strips, with the color ranging from yellow green to dark green. The chart is easy to use and it is the inexpensive tool to determine the greenness of the rice leaf as an indicator of N status of the plant [1,2,3]. Fig. 1(a) shows the LCC from IRRI; each strip has a number corresponds to the greenness level of the rice leaf. In general, the color on the leaf corresponds to the amount of chlorophyll in it. Chlorophyll is a green pigment, present in all green plants, responsible for the absorption of light to provide energy for photosynthesis. There is always a positive correlation between chlorophyll content and nitrogen content in plant leaves [4].

Revised Manuscript Received on May 29, 2019.

Tran Khac Duy, Department of Electronics and Telecommunication Engineering, College of Engineering, Cantho University, Can Tho, Vietnam.

Tran Thi Ngoc Huyen, Department of Electronics and Telecommunication Engineering, College of Engineering, Cantho University, Can Tho, Vietnam.

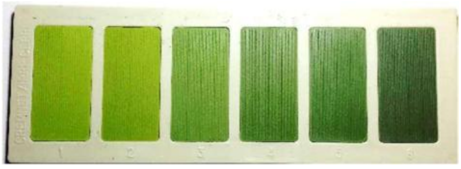
Nguyen Minh Trang,Department of Electronics and Telecommunication Engineering, College of Engineering, Cantho University, Can Tho, Vietnam.

Luong Vinh Quoc Danh, Department of Electronics and Telecommunication Engineering, College of Engineering, Cantho University, Can Tho, Vietnam.

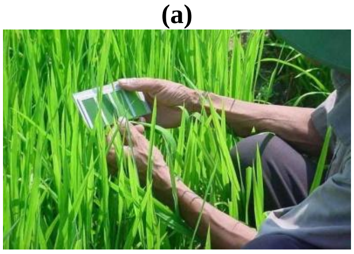
Anh Dinh, Department of Electrical and Computer Engineering, University of Saskatchewan, Saskatoon, Canada

Based on this relationship, the level of greenness on the leaf is used as an indication of the nitrogen status. Nitrogen deficiency in rice most often results in stunted or slow growth and chlorosis with small unit leaf area [5]. It is essential to provide N fertilizer in a timing manner at which the rice isneeded the most in its growing cycle. Rice yield is heavily affected if the crop is not compensated for N deficiency in time [4].

Fig. 1(b) shows how the farmers identify the need for nitrogen in rice using the LCC to read the leaf color. More precise technique is the use of chlorophyll meter (Soil Plant Analysis Development, SPAD), to measure the amount of chlorophyll but this type of system is very expensive which is out of reach for most farmers [6,7]. The farmers just rely on the growing cycle and their eyes to estimate the greenness and determine the need for N. LCC is a better and advance, cheap, easy-to-use method to assist the farmers but the technique still has some drawbacks and time consuming. Direct sunlight affects leaf color readings and the same person should read the LCC at the same time of the day, every time. Taking an average reading between the strips also causes error. The LCC technique is useful but it is not accurate and, in particular, not consistent between readings as it depends on the individual who uses the chart at which time of the day at which weather conditions, not mentioned the effect of other nutrient deficiencies.



(a)



(b)

Fig. 1. (a) Six-strip rice leaf color chart (Courtesy of Cuu Long Delta Rice Research Institute, Vietnam), (b) an example of reading rice leaf to match color with the LCC [1]

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This work attempts to build a compact device which is affordable to the farmers, easy to use in the field, consistent results, not mentioned the capable of IoT and data storage,monitoring, and decision making. The device will assist nitrogen management for cost reduction, higher yield, less labor, and precision farming.

II. SENSOR DESIGN

The proposed prototype system consists of two main parts as shown in Fig. 2. Photograph of the designed prototype is also included in the figure. The first section is the sensing and the second is the data collection.

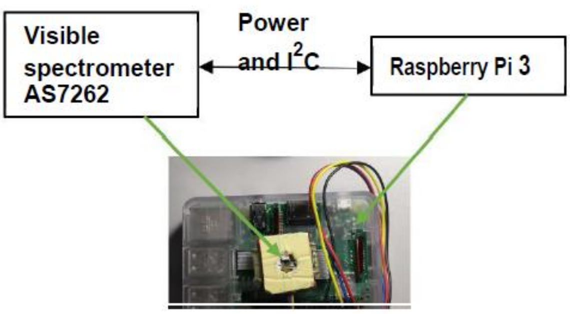

Fig. 2. System overview and device prototype. Leaf samples are to be placed on top of the openning of the spectrometer.

The most important component of the system is the compact, low cost, advanced technology system-on-chip spectrometer, the AS7262 made by AMS [8]. This highly integrated device delivers 6-channel multi-spectral sensing in the visible wavelengths from approximately 430nm to 670nm with full-width half-max of 40nm as shown in Fig. 3. An integrated LED driver with programmable current is provided for electronic shutter applications. Control and spectral data access is implemented through either the I²C register set, or with a high level AT Spectral Command set via a serial UART

In this design, the I²C communication between the spectrometer and the Raspberry Pi is used for controlling the spectrometer and data collection. A 3.3V DC power supply to the sensor is provided by the Raspberry Pi. As seen in block diagram of Fig. 3, the white light strikes on the leaf sample will reflect back to the opening of the sensor. Optical components in the sensor breakdowns 6 wavelengths which strike on the photodetectors and the photodiode voltages are processed and converted into light intensities.

Raspberry Pi (RP) is a common single board computer. The RP has ample computing power and peripherals for many practical applications including IoT and embedded systems. In this sensor prototype, the third model of RP is used to provide power to the sensor and establish communication link to the AS7262. Every second, the VIS spectrometer AS7262 sends 3 sets of 6 numbers representing the amplitude of 6 colors in the VIS spectrum. The RP is programmed (in Python) to receive and save data into a file (in Exel format) while the sensor is in operation. Data files are then transferred to a computer for viewing and processing. Processing data provides 6 levels of the leaf color.

The rice leaf contains green chloroplasts, the organelles that carry out photosynthesis. The chlorophyll is a pigment that absorbs red and blue light as shown in Fig. 4. As seen, the high absorption rate of both chlorophyll a and b is in the 2 regions of the visible spectrum, i.e., the blue color and the red color. From these facts, there are two way to analyze the rainbow spectrum from the visible spectrometer sensor AS7262. The leaf "reflects" green color while "absorbs" blue and red color. It should be less blue and red colors than the green color after the white light strikes on the leaf and reflects back to the opening of the sensor. The useful measurements are the intensities of "green" and "red and blue" spectra.

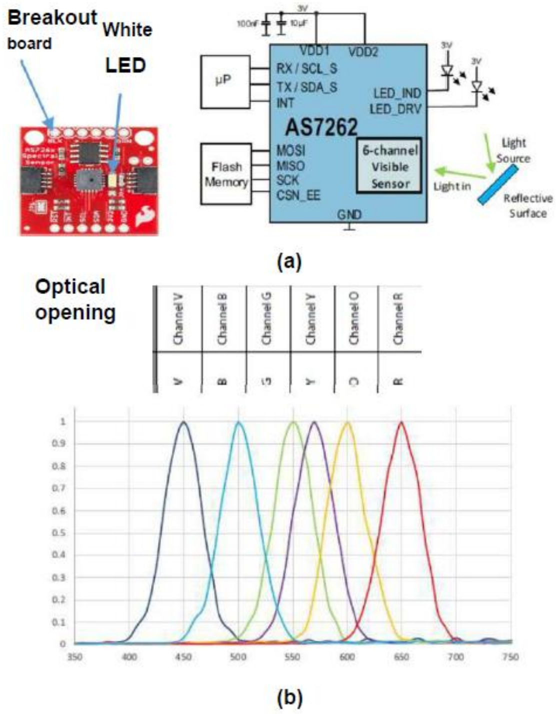

Fig. 3. (a) The visible spectrometer AD7262 to be used with Raspberry Pi: breakout board and block diagram, (b) AD7362 typical optical characteristics (normallized intensity versus 6 color spectrums) [8]

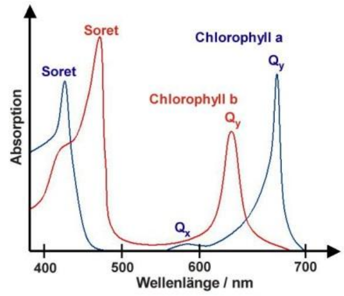

Fig. 4.Cholrophyll spectrum [Wikipedia]

III. EXPERIMEN RESULTS

The prototype was built and tested. A white LED is turn on to provide a wide spectrum of the light, the light is reflected fromthe rice leaf samples and detected by the spectrometer through its opening. The leaf sample are

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placed on top of the opening of the spectrometer. The reflection depends on the level of absorption/transmission of the sample to specific wavelengths. The spectrometer measures the intensity of 6 colors and sends the data to the RP. Data are collected and stored in a file for display and post-processing.

Fig. 5 shows an example of the absorption/transmission spectrum on a full grown longan fruit tree leaf sample in the laboratory environment. As expected, the leaf absorbs and reflects different wavelengths at different rates which are represented by the light intensities in the waveforms of Fig. 5. The most absorption is red color by this leaf while the green and yellowed are reflected the most. This observation can be used to detect the chlorophyll content in the leaf leading to better estimation of nitrogen content. Now the experiments focused on the color of the leaf (green), the same color in the rice LCC because the color chart does not have the capacity to measure chlorophyll content.

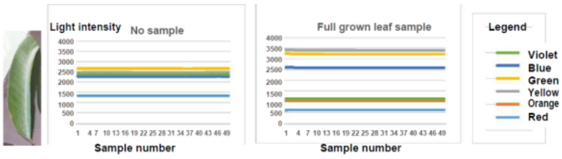

Fig. 5.Absorption/transmission spectrum of no sample and of a full grown longan leaf

Data analysis includes the comparison of the "reflection green" or "absorption blue and red". For the level determination, the reflection green is used and the results are to be compared to the visual readings of the LCC. Fig. 6(a) displays the measurement results of the visible spectrum of the LCC in laboratory environment. The sensor were placed on top of each strip and the sample for 10 seconds. There is a very small difference between strip #4 and strip #5 compared to other strips. By visual inspection of the LCC itself, it is also difficult to distinguish between these two strips. Average values of the strip measurements are to be used to compare with the sample readings in order to determine the strip number of the sample to be measured. Fig. 6(b) shows the plot of the green color and the measurement on a random grass leaf sample. The leaf sample is in strip #3 as its reading is closer to this number.

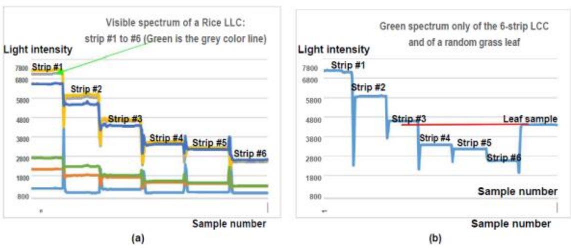

Fig. 6.Laboratory testing (a) Visible spectrum of the rice LCC, (b) Green spectrum only of the rice LCC and of a random leaf sample. The leaf falls to number 3 of the LCC

The device was tested in the field environment in which sunlight will affect the reading therefore the device was covered by a dark enclosure. The leaf sample slides into a slot of the cover for readings. Fig. 7 shows the test results in the field with 4 different rice leaves. Rice leaf #1 was a young leaf and belongs to strip #2.5 while other three are normal healthy leaves (strip #3 or #4).

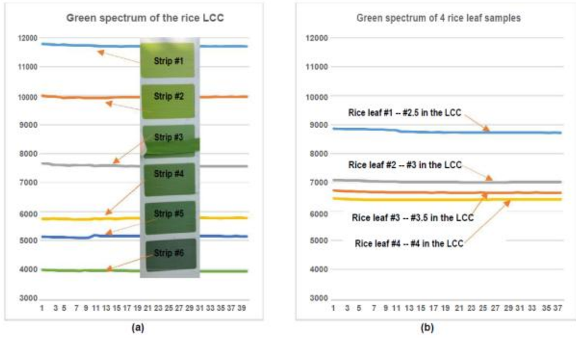

Fig. 7.Field testing, the spectrometer and the samples are in a light-tight chamber, (a) Rice LCC green spectrum, (b) Four rice leaf samples

IV. DISCUSSION AND FUTURE INVESTIGATION

The device can be used to replace the LCC as its readings are fast, more consistent, and more accurate. No calibration or intervene from the users are required by the device. A plug-and-play design makes it friendly and easy to use. It is very simple to extend the functions of the device to support precision farming as IoT can be incorporated since the smartphone will replace the Raspberry Pi in the next prototype. Codes for the RP(or the embedded system) are to be written to display the strip numbers of the LCC after each measurement.

Note that the two wavelengths, blue and red, detected by the visible spectrometer indicate the amount of chlorophyll in the leaf. It is possible to use this device to determine chlorophyll a and b content in the leaf at a much lower cost compared to the SPAD systems. Measuring chlorophyll using the low-cost spectrometer makes more sense and accurate compare to the use of the LCC as the greenness does not truly indicate the N content in the leaf. The level of nitrogen in the leaves can also be used to determine other plant characteristics.

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