Low Cost Portable Plant Nitrogen Deficiency Monitoring System

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Abstract- Plant nutrition is the fundamental need for plant endurance and growth. Lack of necessary nutrients will influence on plant growth and fruit production. Without sufficient amounts of nitrogen in the soil, plants are impotent to produce proteins and nucleic acid required for their growth and survival. Therefore, nutrient monitoring, atmosphere and pest control are the key factors for farmers and agriculturalists. Plant analysis and tissue testing are the two traditional ways to sense plant nutrient content. These techniques are time consuming, destructive and require test samples. Non-destructive testing method is becoming more important due to their advantages. One such equipment is chlorophyll meter (spad meter), which detects the nitrogen content of plant using absorption technique. This meter is expensive and beyond the reach of farmer. Hence a low cost alternative which is as accurate as spad meter is proposed. The proposed non destructive method uses the reflection technique, which senses the leaf transmittance and compares it with leaf colour histogram provided by the agricultural university. Sensor data are further processed to control the status of the nitrogen content in the plant. From the nitrogen status, the quantum of nitrogen fertilizer required will be displayed for the guidance of the farmers.

Keywords – Nitrogen deficiency, optical sensor, microcontroller, reflection technique, non destructive method.

I. INTRODUCTION

Overall requirement for agricultural production is anticipated to enhance by more than 50% within 2050 due to increase in population [1], [2]. Conversely, climatic change, water availability, pollution in atmosphere may lead to low productivity. Nitrogen is one of the most key nutrients of chlorophyll among Carbon (C), Oxygen(O), Hydrogen (H), Potassium (K), Phosphorus (P), Calcium (Ca), Zinc (Zn), Magnesium (Mg), Sulphur (S), and Chlorine (Cl) for plants. Similarly deficiency in nitrogen affects a plant through various ways such as leaf colour, leaf area, leaf weight, plant size, and plant growth. In severe case plant growth may get arrested.

Nitrogen status can be detected using visual diagnosis, soil testing, foliar analysis,[2] plant analysis and tissue testing [3]. These techniques are time consuming, destructive, requires for test sample and so on [4]. The physical limitations of this technology have motivated the researchers to seek for alternative ways to monitor the nitrogen status precisely. In recent times, highly precise nitrogen content in the plant can be estimated using optical sensors [5-7]. There are an extensive varieties of optical sensors available for agricultural application, which begins with sensors to sense the soil quality to sensors set up to detect the protein content. These sensors are working with the principle of soil and plants have unlike relations with illumination of light permitting to spot out its deficiency.

Optical sensors use colour as a measuring quantity. Exclusive research is being carried out to monitor the blood glucose [8] and tea during fermentation [9] and to measure the quality of the specific fruits and vegetables [10]. Further the research is going on with Near Infrared (NIR) sensors. These NIR sensors are popular due to its non destructive nature to measure the nutrient status [11] in addition to access the grading of fruits [5].

Research concerning with non-destructive methods using optical sensors to estimate the nitrogen present in the plant is the recent investigation. Under this category, leaf colour changes can be taken as the parameter to access the nitrogen content in the plant. Very few works have been carried out in real time.

Mark Seelye et. al[12] proposed the automatic monitoring of plant health status for plants growing in a modified micropropagation system. This monitoring system consists of camera, RGB colour sensors, and environmental sensors fitted in the custom built robotic arms for continuous monitoring of the health status of tissue by comparing the sensor outputs to pre-determined optimum values.

C. Witt et al [13] created a standardized leaf colour chart that capture the appropriate range of rice leaf colour in Asia derived from the real colours of rice leaves. They built the four panel leaf colour chart that gives the information pertinent to the status of nitrogen content. Yosef Tabar, S[14] projected to calculate the Nitrogen level of the plant using leaf colour chart and indicate the time at which the Nitrogen fertilizer needs to be applied to the rice crop, specific to rice varieties produced in various regions.

The proposed measurement device is a compact design so that anyone can use without difficulties to measure the nitrogen deficiency in plant such as rice, wheat and maize by sensing the depth of greenness of leaf and it informs the farmer about the amount of Nitrogen fertilizer needs to be applied. Foremost thing in this device is that it is of low cost, so that all farmers can benefit from it.

II. WORKING PRINCIPLE

Greenness of the leaves can be measured using optical sensors that use either reflection or absorption principle. The quantity of chlorophyll present in the leaf can be indirectly measured by estimating the depth of the green colour in the leaf. The farmers can use this technique to examine the nitrogen content in the plant and find out the amount of nitrogen fertilizer required for the plant.This paper proposes a device to measure the nitrogen deficiency in plant by using reflection type of optical sensor, from the leaf colour data, one can estimate the nitrogen deficiency in the plant. The device is calibrated with the leaf colour charts released by agriculture universities in the respective regions. The leaf colour chart is a chart which consists of four or six green colour panels, each colour panel representing a degree of greenness of the leaf which a healthy crop should possess at different stage of its growth. In manual method, the colour of the leaf is compared with the colour panels present in the chart according to the stage of the plant's growth. If the depth of the leaf colour is lesser than the critical colour in the leaf colour chart, thus the plant has nitrogen deficiency. The manual method may lead to low accuracy due to human intervention. To overcome this drawback, automatic nitrogen deficiency detector based on the above principle is developed.

III. MEASUREMENT SYSTEM IMPLEMENTATION

The low cost measurement system is implemented using two major components namely microcontroller and colour sensor and is shown in Fig.1.The developed nitrogen deficiency detector is built using the four LED, colour sensor (TCS3200), Microcontroller (MSP 430G2553), LCD display and push button switches shown in Fig.1 and it can assess the leaves thickness up to 2mm . The device has test area where a leaf should be placed and four LED source will illuminate from the top of the aperture at wavelengths, red at 650nm and of NIR at 940nm, the reflected light is sensed using a colour sensor (TCS3200). The colour sensor detects the colour of the leaf placed under the test area and generates a frequency corresponding to it and it is fed to the microcontroller (MSP 430G2553). The microcontroller counts the number of square pulses sent by the colour sensor. This leaf colour count value is taken as the indicator to access the degree of green colour present in the plant. The leaf colour count is correlated with the leaf colour chart provided by the agricultural universities to create a look up table data. This look up table data is preloaded in the microcontroller and it is used to detect the nitrogen deficiency in the plant. Then, the microcontroller sends the information to LCD display about the nitrogen fertilizer requirement by comparing the sensor reading with the look up table data.

The MSP 430G2553 consists of an in-built clock which makes easy to design supporting components required for the chip. It is twenty pin chip with two ports. The chip supports different clock speed of 1, 8, 12 and 16MHz.To synchronizes the chip with the colour sensor, it was made to run at 8 MHz.There are several optical sensors available in the market. One among them is TCS3200 and it is a Light-to-Frequency convertor. TCS3200 has built-in matrix 8*8 photodiodes. It is capable of sensing three different colours red, blue and green. For each colour 16 photodiodes are used to sense the colour and remaining 16 photodiodes are used for clear.

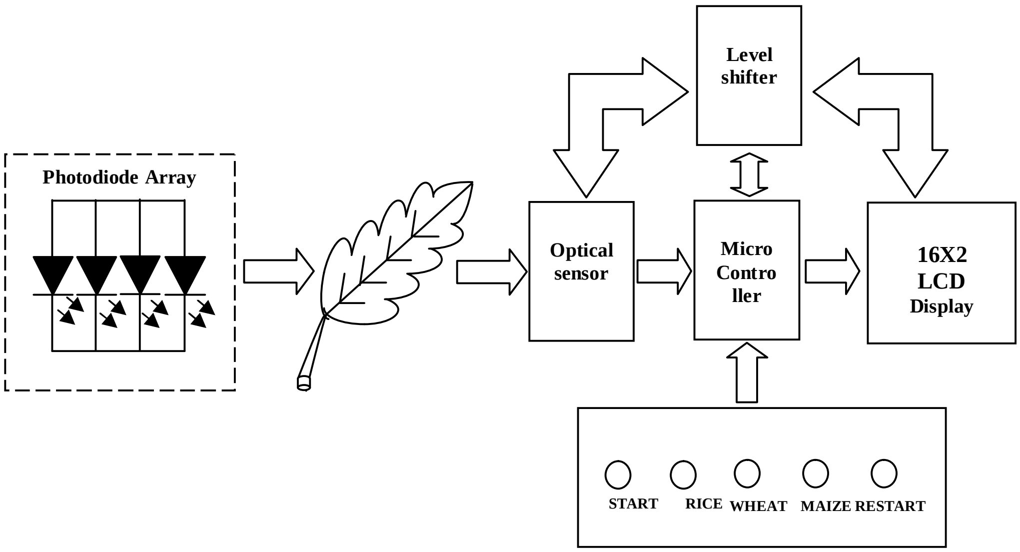

Fig.1Block diagram for Nitrogen deficiency detector

IV. PROCEDURE FOR DEVICE OPERATION

When the device is switched on, the LCD will show "Place the Sample & press START". The device has a leaf area on its top right corner where the leaf should be placed. After the leaf is placed, the user should press the START button. Once the START button is pressed, the four LED emits the light signals at 650nm and 940nm. The colour sensor senses the light signal. Then device initializes the sampling process by showing a message "SAMPLING STARTED". The microcontroller counts the square pulses generated by the colour sensor. Once the leaf colour count is counted, microcontroller stores this data in the register and it sends a message to the display as "SAMPLING COMPLETED". And then the sensor reading will be displayed within a second on the LCD screen. Subsequently the microcontroller sends the message as "Select Ur Crop" in the display. Then, press the appropriate crop push button i.e. Rice, Wheat or Maize. Now, Microcontroller compares the leaf colour count with the look up table data corresponding to the crop. If the comparison is completed, the leaf colour count value will be displayed, after a few seconds, the device displays the nitrogen status as "Adequate", "Inadequate" or "Excess" depending upon the leaf colour count. This device has sufficient in-built memory, so that it can store around 1000 readings and it can assess the nitrogen deficiency status of any plant by providing the leaf colour histogram. The proposed measurement system has been assembled, tested and calibrated with the existing measurement device, like spad meter. The readings are approximately matching.

There are two pins to select the filter. The gain of output of the TCS3200 can be varied with the 2 pins. There are 4 LED's which provide light source to surface of the leaf. The next important element for this device is a level shifter,(CD4050). MSPG2553 works on 3.3V whereas TCS3200 works on 5V. CD4050 acts as a communicator between MSPG2553 and LCD. It converts 3.3V signal from processor to 5V signal for LCD and 5V signal form LCD to 3.3V signal for the processor. There are two voltage regulators UA78M33 and UA78M05 used for regulating the voltage level of 3.3V and 5V respectively.

V. CALIBRATION OF DEVICE

The key role of the device is to get the data from the optical sensor. The optical sensor senses the reflected signal from the leaf samples. An open source software Energia is used to write the program in MSP430G2553 microcontroller for receiving the data from the sensor using timers, interrupts and ports. The program is written as per the flow chart shown in Fig.2

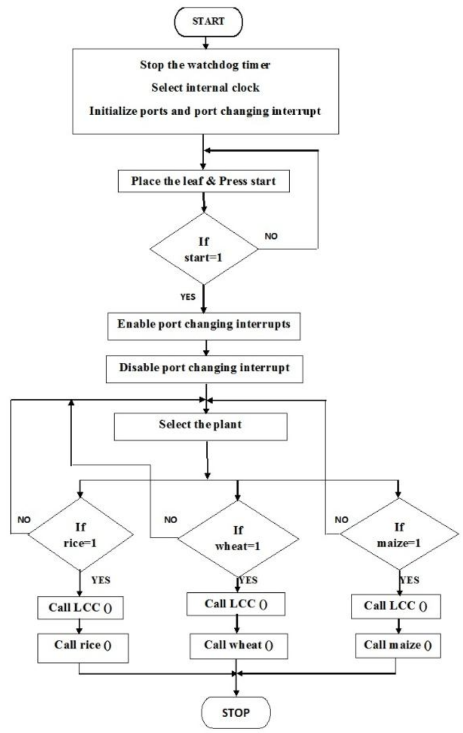

Fig.2.Flowchart for finding the nitrogen deficiency detector

The first step is to find out the leaf colour count of the leaf under test. The leaf colour count is the counter value of the microcontroller that detects the time period of the square wave generated by the optical sensor. The optical sensor generates the different frequency wave depending upon depth of the greenness of the leaf. Time period is inversely proportional to the frequency and it is correlated with leaf colour count. The timer is started at the rising edge of the square pulse and the timer is stopped at the rising edge of the next square pulse, illustrated in Fig.3

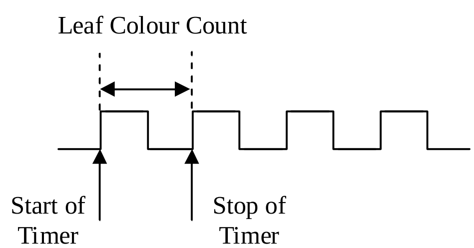

Fig..3 Illustration of finding the Leaf colour Count

Timer 1 and a port changing interrupt is used to find the leaf colour count value. Port changing interrupt is a programmable interrupt where interrupt can be programmed to the rising edge, falling edge or change in port. For this application, rising edge is assigned as the port changing interrupt. The timer is switched on when the port changing interrupt occurs for the first time. The next time when port changing interrupt occurs, the timer is stopped. The timer value is stored to a variable and the timer is reset when the port changing occurs for the third time.

Next step is to select the crop according to the test samples. If the leaf is Rice, it goes to the function Rice().The Rice function is used to detect the nitrogen content in the rice plant using the look up table. The look up table contains the leaf colour count and its corresponding nitrogen content in plant. The values are grouped into three categories viz.,

- Nitrogen Inadequate
- Nitrogen Adequate
- Nitrogen Excess

The Leaf colour count for the three categories can be seen in the display. If the value lies in Nitrogen Inadequate region the liquid crystal display shows "Add Nitrogen Fertilizer" message to the users. Similar procedure is followed for wheat and maize.

VI. CALIBRATION OF SENSOR

Calibration is very important for this device. Sensor reading can vary with ambient light also. Hence, elaborate arrangement was made to minimize entry of ambient light. Leaf is inserted and a lid is closed covering the leaf, so that only light from the device alone falls on the leaf and gets reflected. First, calculation was done in the laboratory using the six panel leaf colour chart, available for rice. Count value is taken for each colour panel has been noted and presented in Fig.4. . The count value of the controller can be calculated using the equation as follows.

$$count\ \ value = \frac{clock\ \ frequency\ \ used}{frequency\ \ input}$$

Three samples of rice leaf covering nitrogen inadequate, nitrogen adequate and nitrogen excess conditions are collected. They are inserted into the device and count values noted. These leaves are compared physically with six panel leaf colour chart. From this, the count value bands for nitrogen inadequate, nitrogen adequate and nitrogen excess were determined and stored in the device. Now the device is ready for operation.

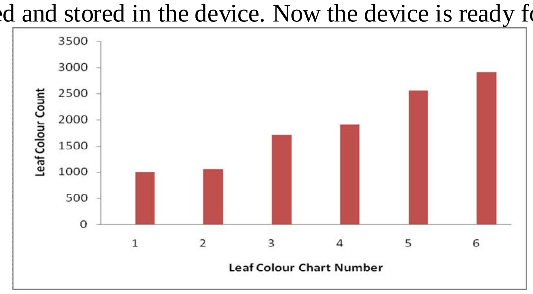

Fig.4.Calibration of TCS3200 without proper cover for rice plant

VII. RESULTS AND DISCUSSION

The agricultural university provides the leaf color chart with the amount of nitrogen fertilizer required for the each color in the chart. From this leaf color chart, the depth of the green in the leaf can be manually matched with leaf colour chart as shown in Fig.5 by placing the leaf in the closer to the respective colour. But it gives inaccurate results due to human interventions. To overcome this drawback, the automatic plant nitrogen deficiency detector is developed and tested in the field for the maize crop as shown in the Fig.6.

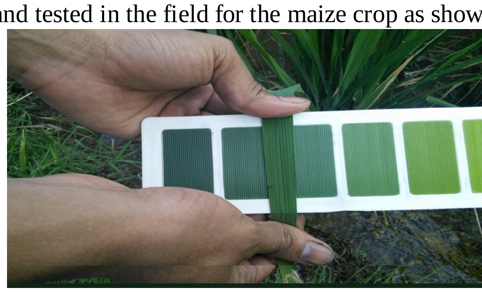

Fig.5. Leaf colour chart

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Fig.6. Field test with maize crop

The readings are taken to twenty days old maize plant of its growth stage. Three readings were taken for three different leaf colors as shown in Fig.7. The first one was a light green color leaf matching the first panel of the leaf color chart, second was matching the fourth panel of the leaf color chart and the last sample matching the sixth panel of leaf color chart

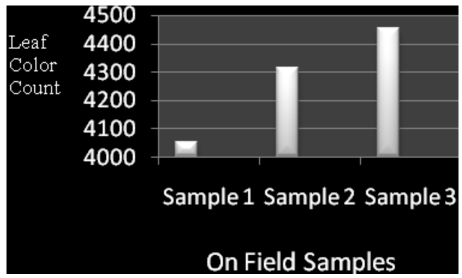

Fig. 7. Measurement of Leaf colour count for maize crop test samples

The readings are taken for the Rice crop as shown in Fig.8.

Fig 8. Field test with Rice crop.

VIII.CONCLUSION

Though leaf colour charts can do such jobs, it is prone to error as farmers can make mistake in colour comparison. Low cost device developed and reported here obviates the necessity for manual judgement and gives the output in digital display clearly. Display can be made in local languages also, to help farmers who are less educated and can not understand English language. Being a programmable device, several crops can be added, produced data can be made available. Colour count value may differ from region to region. Leaf colour may be analysed in the laboratory using expensive SPAD meter and colour count value can be calculated. There values can be programmed in this local portable meter, which is now regionalised. However, schedule for taking the reading, quantity of nitrogen fertilizer per acre etc. are all determined by agriculture university/college, Government/Private agencies who are vested with the responsibilities of advising farmers in that region.

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