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Research Article

Multi-crop Chlorophyll Meter System Design for Effective Fertilization

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Abstract: The aim of this article is to design a key device for the management of Nitrogen (N) concentration in the crops for an effective yield. In leaves, the chlorophyll content is estimated through the chlorophyll meter which detects the optical signal (light) between the wavelengths 450 nm and 950 nm. The received optical light in each wavelengths are determined. Chlorophyll takes 425-450 nm optical signals and consequently, the acquired of the wavelengths penetrating through the leaves is diminished if it is compared with the reception of 650-670 nm light. The light of 950 nm wavelength is uninterrupted due to chlorophyll level in the leaves and the received light acts as an indicator to determine the hairy or waxy presence on the surface of the leaves. In the test field, major methods find out the collection of N status, processing, soil analysis and the samples of plant tissue but with the help of handy chlorophyll meter, the level of chlorophyll as well the N availability can be predicted on several crops. By using an 8 bit microcontroller, light emitting diode, photo diode and amplifier, the leaf chlorophyll content has been measured for different crops like turmeric, sugar cane and plantain etc. Field measurement manifests nitrogen content in terms of percentage as shown in 6 levels of Leaf Colour Chart (LCC). And also infers that chlorophyll absorbs more at 425-450 nm than 650-670 nm light.

Keywords: Chlorophyll, fertilization, microcontroller, nitrogen, photo absorption, photo sensors, portable meter, spectral analysis

INTRODUCTION

High Chlorophyll, a green photosynthetic pigment that helps plants to get energy from sunlight plays a major role in increasing the yield of crops. In recent years, agriculture and crop production has been handled through engineering technology in order to attain potential results. Though there are several methods available in literature to measure the chlorophyll content in plants, chlorophyll meter is considered as one of the effective methods to calculate the quantity of Nitrogen (N) fertilizer wanted for paddy (rice) crops. Moreover, one of the essential factors is that the retrieval effectiveness of the fertilizer (N) in rice field is tarnished which results in high risk of nitrate pollution in water. So, organizations have recommended some methodologies and plans to monitor the N level on the rice crops and hence the cultivators would come to know the proper level of N fertilizer required for their rice fields. Peterson *et al*. (1993) presented a method that has been typically used to evaluate the chlorophyll content is the Leaf Colour Chart (LCC) developed by Furuya (1987). LCCs are being used in most of the areas with certain regulations to cultivate desired and required rice breeds as described in Islam *et al*. (2007). In an another method, a single wavelength of 562 nm peak value is used to transmit towards the surface of leaf by using green LED and the light which scattered at a specific angle is received by photo detector and the received wave is processed by PIC Microcontroller and produces any one of the 6 different contrast of green colors as output (LED) based on the available chlorophyll content in corresponding leaf as discussed in Sumriddetchkajorn and Intaravanne (2010, 2014). Though these methods have a great effect on measuring the nitrogen content, the main drawback is that it has been used only for one crop. This study overcomes the above mentioned limitation in a way that this approach can be effectively applied to more than one crop.

Importance of chlorophyll: Chlorophyll is an essential aspect in the plant which helps in photosynthesis as described in Farabee (2010). Chlorophyll is an accessory biochemical constituent in the molecular apparatus which is important for photosynthesis. It is a process between CO2 and H2O which happens by using sunlight to make glucose, oxygen and a waste product. Chlorophyll helps in this reaction, by getting sun light energy:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \quad (1)$$

The chemical Eq. (1) shows the importance of chlorophyll in the process of photosynthesis. By that process, the nutrients like protein, vitamin and glucose

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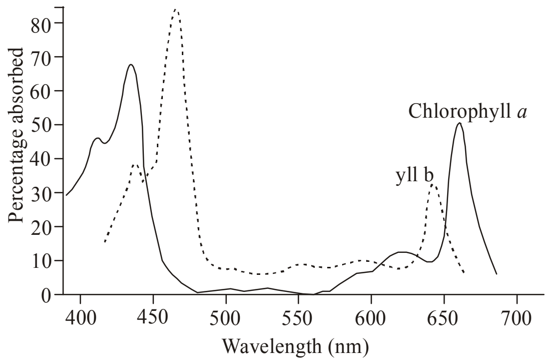


Fig. 1: Absorption spectra

can be produced by plants itself whereas animals cannot make nutritive substance on their own. Chlorophyll is similar to the oxygen and CO2 carrying heme group found in hemoglobin (Evans, 1983). Phorphyin structure in Chlorophyll contains magnesium and hemoglobin contains iron. As metathesizing chlorophyll increases haemoglobin in the blood, vegetarian animals survive life by consuming green grass alone (Wolf, 1956). Chlorophyll Fig. 1 represents leaf chlorophyll absorption with respect to different wave lengths. Chlorophyll A and B are the two kinds where chlorophyll A gets its power of energy from wavelength of orange-red and violet-blue light. Chlorophyll B gets its power of energy at green light wavelengths.

Chlorophyll a cannot function well without the help of Chlorophyll b and Chlorophyll b cannot effectively produce enough energy on its own. Hence, the plants need Chlorophyll a than Chlorophyll b.

Importance of nitrogen: Nitrogen in the soil plays a vital role in the development of plant. Adequate nitrogen is needed in the soil to avoid plant degradation. Nitrogen is a major part of Chlorophyll and the green color of plants (Peterson *et al*., 1993). It is much needed for the significant growth of the crops. The inadequate nitrogen will affect both growth and photosynthetic processes of the crops. In general, nitrogen evaporates easily. Moreover, it gets washed away when the plant is watered too much or receives excess rainfalls.

It is necessary to initially analyze and understand the nature of the soil and plant the crops accordingly. The analysis would facilitate the monitoring of the available nutrients such as NO2, phosphorus, potassium and then add the nutrients accordingly for the maximum growth of plants. Early spring is the suitable time in testing the soil where the microbes' adjust and react to the corrections.

When the nitrogen falls below optimal level as per the reading on the kit, nitrogen rich sources such as blood meal, fish meal and animal waste can be added and a cover crop of alfalfa, soya beans or clovers which actually put nitrogen back into the soil could also be a better choice (Singh *et al*., 2002).

MEASUREMENT OF CHLOROPHYLL

Leaf Color Chart (LCC) is taken for the measurement of the nitrogen content available or taken from the soil (Witt *et al*., 2005). Figure 2 is the example for LCC. LCC is an inexpensive and an easy to use tool to monitor the greenness in rice crop which is an indicator to determine the level of nitrogen in crops and it is also an alternate for chlorophyll meter (Follet *et al*., 1992). Therefore LCC becomes useful in avoiding under or above fertilization besides maintaining the appropriate time (Budhar, 2005; Yang *et al*., 2003). The application of LCC for nitrogen management has constantly increased the yield and profit in comparison to the farmers' fertilizer practice in Bangladesh (Alam *et al*., 2005; Baksh *et al*., 2009; Alam *et al*., 2009). Figure 2 shows the LCC of 6 panels for paddy.

The excess N content may contaminate the ground water considerably. The main objective is to design a module of chlorophyll meter to measure the chlorophyll and nitrogen content in crops for effective fertilization to increase the yield without degrading the fertility of the land and the quality of ground water. There is a closed relationship between the concentration of N and chlorophyll in the leaf since chlorophyll molecules contain higher level of N (Peterson *et al*., 1993). Though the concentration of the chlorophyll are the greenness of the leaves is affected due to various factors like N level of the plant, the meter is able to determine the deficiencies of N and also assures as a fine tool to improve N management (Peterson *et al*., 1993; Smeal and Zhang, 1994; Balasubramanian *et al*., 2000). SPAD (chlorophyll meter) readings indicate leaf chlorophyll content, thereby providing an assessment of leaf N status indirectly (Blackmer and Schepers, 1994). To determine the chlorophyll quantity in crop

Fig. 2: Nitrogen concentration increases

leaves Chlorophyll meter detects the received optical signals between 450 nm and 950 nm (Watanabe *et al*., 1980). In the field, Common strategies used to measure N status are process and analysis of soil, tissue samples of plant etc. Hence, nitrogen (N) measuring meter has both economic and environment viability.

- The methodologies that are used to extract the chlorophyll in plants so far are depends on:
- Extraction of leaf tissues by using solvents which includes dimethyl sulfoxide (DMSO), acetone, methanol, Nitrogen, petroleum ether and N-dimethyl formamide, etc
- Determining the leaf's greenness in comparison with green color strips of various intensities
- Observing the growth and the appearance of the leaves
- The disadvantages in the existing systems are as follows:
- No precision
- Complex Chemical process methods
- Requires long period to determine the chlorophyll content
- Expensive Chemical processes
- Needs technical persons to perform the chemical processes.

MATERIALS AND METHODS

Our proposed method of chlorophyll meter overcomes the aforementioned disadvantages and helps to fertilize the crops. A portable and diagnostic tool measures the (chlorophyll) greenness and the concentration of chlorophyll in leaves. The meter instantly makes the non-destructive reading on a plant on the basis of light intensity absorbed by the leaf samples. Estimation of the chlorophyll quantity of leaves is measured by passing the light at wavelengths of 450 nm to 950 nm. Photodiode is used to detect the wavelength of ambient light received. Chlorophyll absorbs 425-450 nm blue light and as a result, the reception of that light at the photodiode is decreased

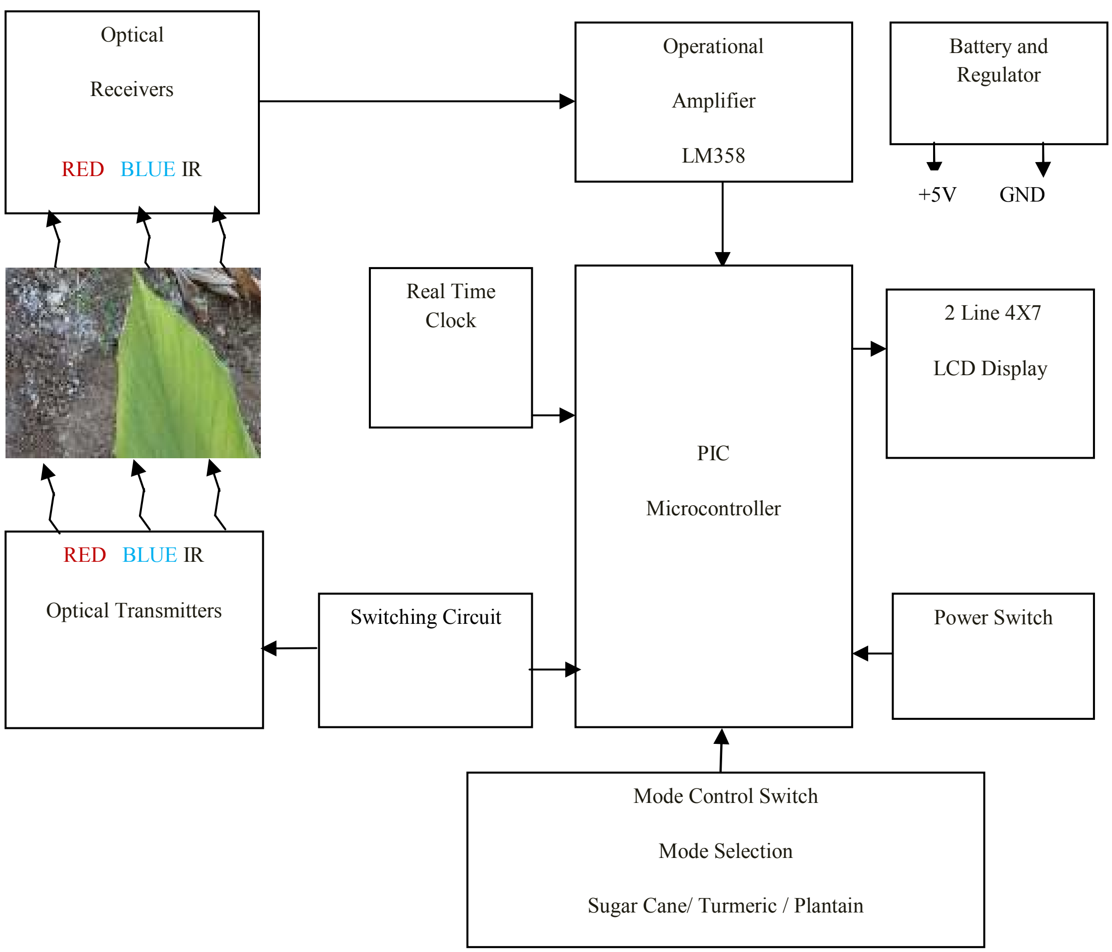


Fig. 3: Block diagram of the system

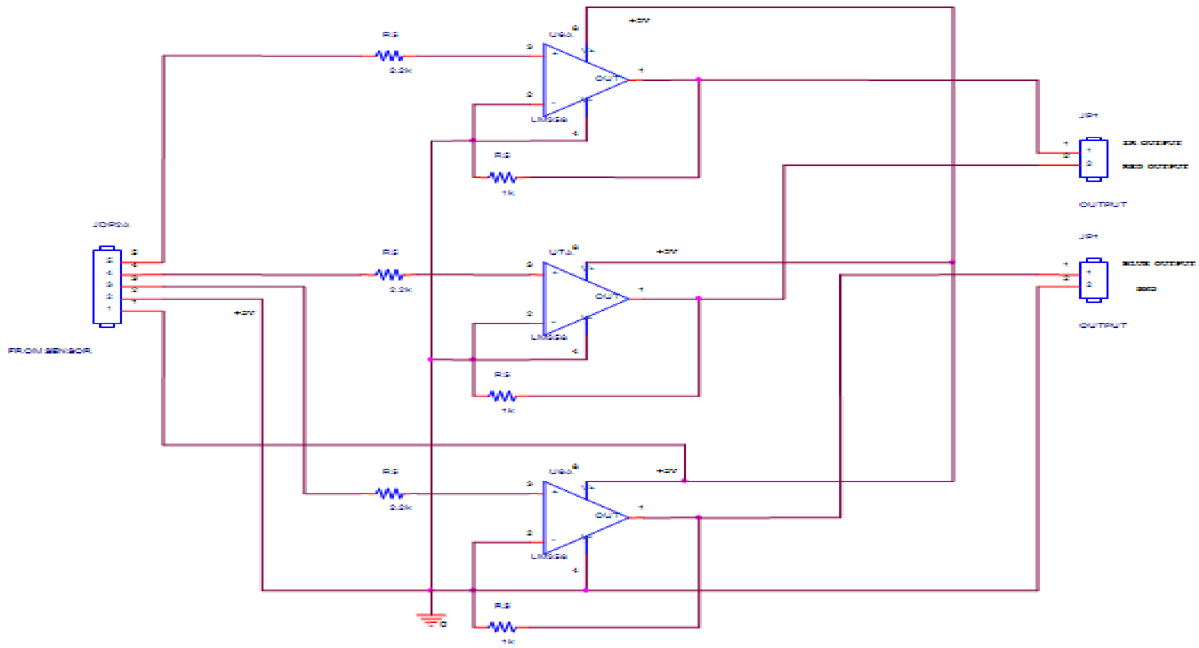


Fig. 4: Circuit diagram of an amplifier unit

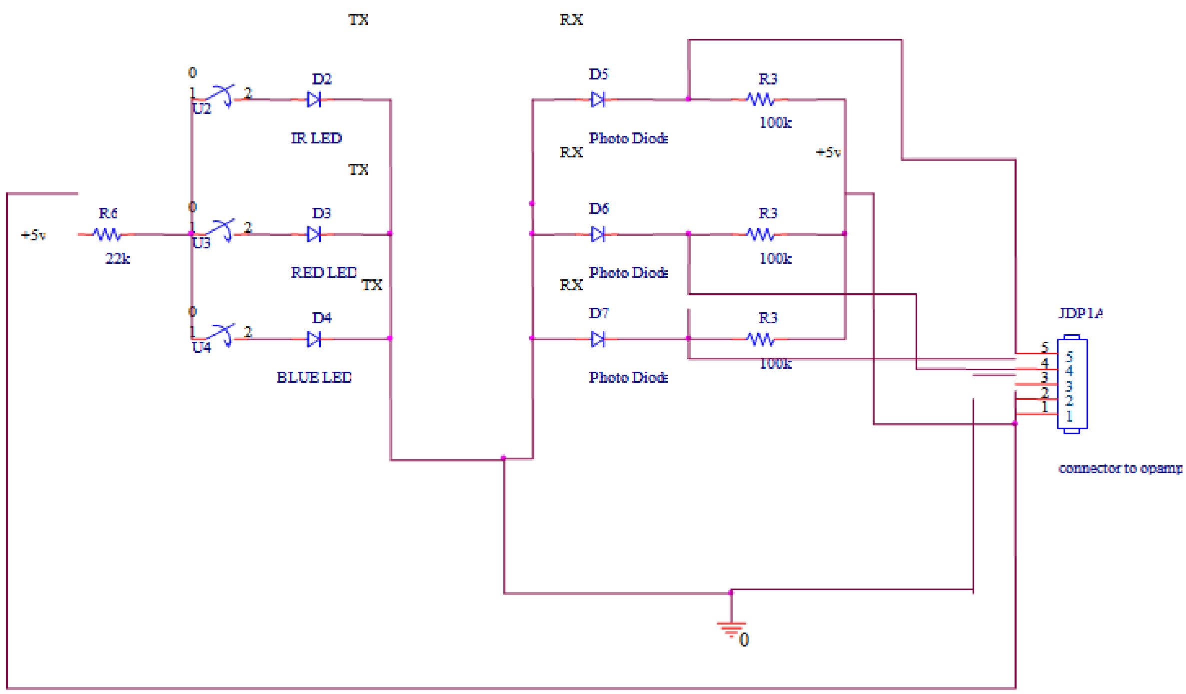


Fig. 5: Circuit diagram of the photo sensor unit

due to the absorption of leaves. Chlorophyll also takes 650- 670 nm red light and thereafter, the light reception at photo diode is decreased due to the absorption of leaves. The presents of hairy or waxy surface of leaves show the physical characteristics which absorb 950 nm infra-red light and as an outcome, the reception of that light is decreased due to the absorption by leaves. Thus, from the reception of the light at three photodiodes after the absorption of leaves from three different photo sources, we can determine the amount of chlorophyll content and the nitrogen content also the leaf texture content. Figure 3 shows the block diagram of the whole system.

Optical signal amplifier: Figure 4 shows the circuit diagram of amplifier unit.

Table 1: Specifications of photo sources

LED Colour	Part No	Typical wavelength (λ) nm	Die material	Operating voltage V	Size mm
Blue	VL-425-3-20	425	InGaN	3.2	3
Red	B3B-446-30	660	GaAIAS	1.9	3
Infrared source	ELD-950-535	950	AIGaAS	1.4	5

Hardware description: A single power supply with a wide operating voltage, frequency-compensated and high-gain amplifier (LM 358) design includes two independent amplifiers is shown in Fig. 5.

Optical detector:
Mode selection: To measure chlorophyll content and the other parameters of various crops (Turmeric, Sugar cane and Plantain), a mode selection switch is used to enter into the corresponding crop reference value.

Field work: A fieldwork has been made:

- Among different varieties of Crop -3 leaves from each Crop, 3 readings from each leaf (shoot, middle, tip)
- In different localities
- Over different time periods-morning, afternoon and evening

Software development: The following Fig. 6 flowchart represents the software operation.

This project aims to measure the nitrogen availability of the crops. There by, the fertilizer is used effectively and economically to harvest a high yield. The fertility of the land is also intertwined with the fertilization. An optimum level of fertilizer should be used in order to maintain the fertility of the land. The excess amount of fertilizer will affect the fertility of the land where as, the less amount causes low yield. The quality of the ground water and its contamination is also linked with the fertilizer level used.

This project determines the amount of chlorophyll and nitrogen content in the crops using the spectral analysis of the leaves. The Chlorophyll meter senses light at wavelengths of 425-450 nm (blue spectra), 650-670 nm (red spectra) and 950 nm to estimate the quantity of chlorophyll, nitrogen and the physical texture of the leaves, respectively.

This chlorophyll meter consists of a photo sensor unit to determine the leaf characteristics by spectral analysis. The photo sensor unit consists of three photo sources and three photodiodes for generation and detection of the three wavelengths. The specifications of photo sources used are shown in the Table 1.

To detect the said wavelengths, Si PIN (S5821) photodiodes with the sensitivity range of 320 to 1100 nm are used. The photo sensor unit is projected outside meter in order to make it convenient to clip with the leaves of the crop. The outputs of the sensors are amplified with operational amplifiers LM358. The amplified sensor values are analog signals. PIC 16F877A microcontroller is used to process the output of the photo sensor unit and display the amount of chlorophyll and nitrogen in the plants. PIC 16F877A is mainly used because of its in-built analog to digital converter unit (A/D). It has five I/O ports: port A, B, C, D and E. The meter uses three I/O ports B, C and D for receiving the output of the three photodiodes from the three channels of the A/D unit.

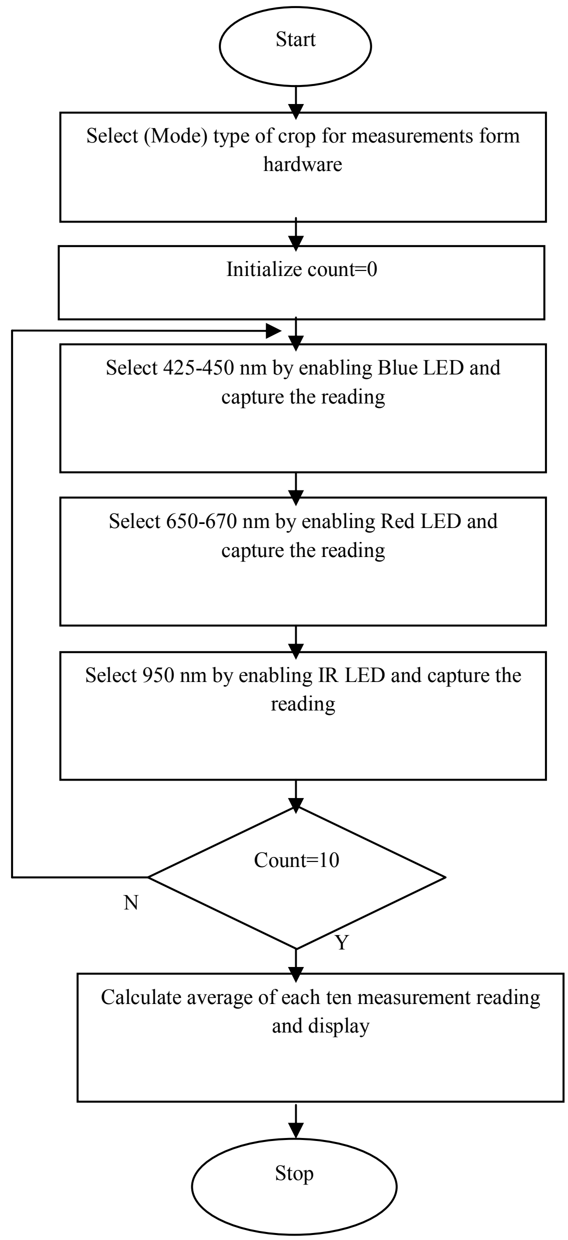


Fig. 6: Flow chart of software operation

Fig. 7: Hardware unit

Table 2: Amount of chlorophyll, nitrogen and physical texture content available in the turmeric leave

	Figure 8					
Parameter	(a)	(b)	(c)	(d)	(e)	(f)
Chlorophyll at 450 nm (Nitrogen) (%)	35	41	60	82	82	70
Chlorophyll at 650 nm (Nitrogen) (%)	20	22	22	40	41	31
Physical texture at 950nm (%)	20	30	33	40	39	25

The meter has been calibrated (six leaf colour chart into percentage scale) for the major commercial crops like turmeric, sugar cane and plantain that is cultivated all around the year. Sample readings were taken from the crops in various fields and localities. The readings were tabulated and analyzed and it is used in the programming of the controller to determine the chlorophyll and the nitrogen content of the crops.

The voltage readings tabulated were analyzed, averaged and based on the readings, the percentage of the chlorophyll and the nitrogen were determined by the microcontroller. Calculated readings are displayed using an alphanumeric LCD display connected to the port of the microcontroller.

All the components are powered with the Lithium-ion battery and a regulator circuit which supplies a constant 6V dc. The Lithium-ion battery makes the meter portable which is one of the primary features and is also rechargeable which gives it a long life period. Figure 7 shows the complete product of our proposed method.

RESULTS AND DISCUSSION

Turmeric leaf testing: The above Table 2 gives the amount of Chlorophyll, Nitrogen and physical texture

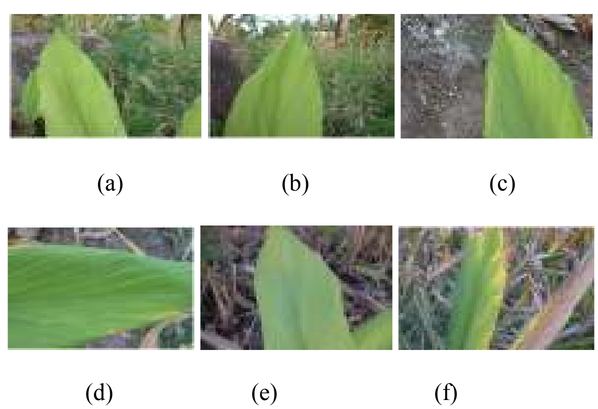


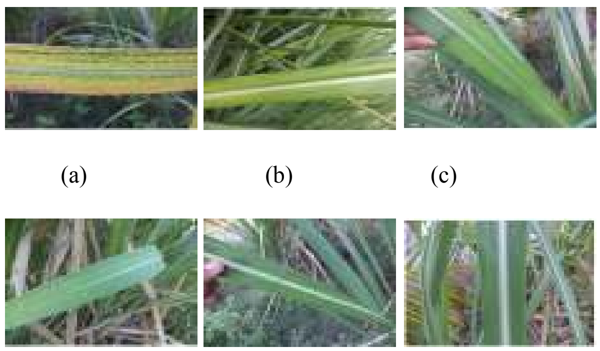
Fig. 8: Amount of chlorophyll, nitrogen and physical texture content in turmeric leaves

Table 3: Gives the amount of chlorophyll, nitrogen and physical texture content available in the sugar cane leaves

	Figure 9					
Parameter	(a)	(b)	(c)	(d)	(e)	(f)
Chlorophyll at 450 nm (Nitrogen) (%)	15	17	35	75	82	90
Chlorophyll at 650 nm (Nitrogen) (%)	5	7	15	33	42	49
Physical Texture at 950nm (%)	70	74	82	85	88	90

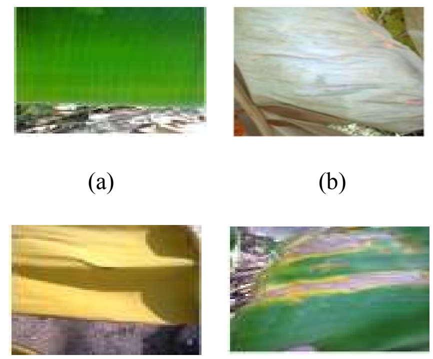
Table 4: Gives the amount of Chlorophyll, Nitrogen and physical texture content available in the banana leaves

	Figure 10			
Parameter	(a)	(b)	(c)	(d)
Chlorophyll at 450 nm (Nitrogen) (%)	55	5	8	40
Chlorophyll at 650 nm (Nitrogen) (%)	20	2	5	10
Physical Texture at 950 nm (%)	20	5	8	15



(a) (b) (c) (d) (e) (f)

Fig. 9: Amount of chlorophyll, nitrogen and physical texture content in sugar cane leaves



(a) (b) (c) (d)

Fig. 10: Amount of chlorophyll, nitrogen and physical texture content in banana leaves

content available in the turmeric leaves(in terms of percentage) which is in the Fig. 8a to f.

Sugar cane leaf testing: The above Table 3 gives the amount of Chlorophyll, Nitrogen and physical texture content available in the sugar cane leaves (in terms of percentage) which is in the Fig. 9a to f.

Platain leaf testing: The above Table 4 gives the amount of Chlorophyll, Nitrogen and physical texture content available in the banana leaves (in terms of percentage) which is in the Fig. 10a to d.

Features:

- Portable
- Low cost
- Compact
- On the spot chlorophyll reading-no need for further process
- Designed for the major commercial crop-(Turmeric, Sugar cane and Plantain)

CONCLUSION

Thus the meter determines the chlorophyll and nitrogen content of the leaves and displays in percentage. It helps the agriculturists to fertilize their land accordingly and improves the crop yield without degrading the fertility of the land. The contamination of the ground water is also prevented by fertilizing the crops to their needs. The project can be extended to various other commercial crops by doing field study and performing changes in the program embedded in the microcontroller and it is just a prototype of chlorophyll meter. Various optimizations can be brought into the programming methodologies to improve the accuracy of the meter. The key advantages of the chlorophyll meter are its portability, on the spot chlorophyll measurement with less cost and long life period.

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