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Nitrogen Adequacy Measurement in Rice (*Oryza sativa* L.) by Automated Methods based on Leaf Color Chart (LCC): A Review

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Abstract

Rice (*Oryza sativa* L.) is the staple food for over 50% of the world's population. For elevated growth yield and quality of product, sufficient delivery of nitrogen (N) is required to the crop. An effortless gadget that can be used to determine the color of the leaves of rice plants for quantifying N fertilizer is the Leaf Color Chart (LCC). However, the difficulty in this LCC is that the tool is still manual and color estimation is done through eye sight. To overcome these difficulties, it is essential to have an automatic classification system of rice leaf color that can facilitate farmers in finding the category of rice plants depending on LCC. Studies have revealed that the color classification system of rice leaves have an accuracy rate of 75%. Customized leaf colour chart (CLCC) based N application enhanced yield by 10.3 to 13.3 % and 9.9 to 10.9 % over conventionally applied urea in direct seeded rice and transplanted rice, respectively. Color classification by these two proposed methods achieved 94.22% accuracy in CNN Model and 91.22% accuracy in the DT classifier. LCC-N management during Thaladi season for ASD 18 revealed that LCC measurement at critical growth stages resulted in the conservation of 70 kg N ha^{-1} compared to the blanket N of 150 kg N/ha in three splits. By LCC method average saving in N was 25 kg ha^{-1} without any reduction in yield. These, review results clearly reveal the importance of LCC for precision nitrogen management in rice crop.

Keywords: Leaf colour chart, nitrogen, productivity, rice, sustainability

1. Introduction

Paddy (*Oryza sativa*), a major crop cultivated globally in an area of 165.04 million hectares with an average productivity of 47.05 q ha^{-1} (Anonymous, 2023). In India, with a production of 172.58 million tons and productivity of 4229.4 kg ha^{-1} rice cultivation covers an area of 46.4 mha (Anonymous, 2023). It is the staple food for over half of the world's population (Somaweera et al., 2016) and provides 30–60% of the calories consumed by them. It is one of the input intensive crops in the world. At present rice production alone consumes nearly 24.7 mt of fertilizer ($N+P_2O_5+K_2O$) which accounts for approximately 14.0% of the total global fertilizer consumption in a year and in India it accounts for 31.8% of the total fertilizer consumption. Since nutrient is a key input for enhancing productivity and profitability in rice cultivation, extensive research has been done to develop and optimize appropriate nutrient management strategies for rice and rice based systems in varying agro-ecological conditions. To meet up the rising demand for rice and guarantee sustainable production, efficient management of nitrogen fertilizers is essential (Midya et al., 2021).

Most of the early researches were focused on broad based blanket recommendations of nutrient application for similar agro-climatic regions. However, these recommendations did not consider the spatial variability such as field-to-field variability of soil nutrient status which often leads to either excess or deficit application of nutrients resulting in loss of nutrient, reduced yield, poor nutrient response and low nutrient use efficiency. The average recovery efficiencies of N, P, and K from applied fertilizers are low in rice field which varies from 35–40%, 20–25% and 35–40%, respectively. Considering the fact that relationship between soil fertility status, nutrient use efficiency and yield at farm level is highly scattered having a great degree of variation, a common nutrient management strategy may not be appropriate for farmers of different agro-ecology and socio-economic background. Efforts have been made to upscale the data base with respect to soil fertility management from field level to regional level by delineating the management zones of rice cultivation using GIS, GPS and remote sensing tools. During the past few years' tremendous progress have been made in the nutrient management research in order to satisfy "4 R" criteria i.e. right dose, right time, right source and right place, for enhancing the nutrient use efficiency on field (Nayak et al., 2018). This led to development of numerous tools and technologies that can be used in rice cultivation across the agro-ecosystem such as soil test crop response (STCR) based N, P, K recommendation , site specific nutrient management (SSNM) using omission plot technique and targeted yield approach, real time N management (RTNM) using leaf colour chart, rice crop manager, chlorophyll meter, soil health card, green seeker, use of enhanced efficiency fertilizer materials (EEFs) such as urea super granules, coated urea, neem-coated urea (NCU), nano fertilizers etc. However, these tools and technologies need to be simplified while retaining their effectiveness to ensure large scale adoption by the small and marginal farmers growing rice. In this review use of LCC for measurement of nitrogen adequacy in paddy was discussed.

2. Nitrogen in Crop Management

Nitrogen is one of the most essential and most limiting nutrients for rice production (Wahiddin et al., 2020). In the process of maintaining the quality of rice plants in order to have good growth and high yields, an adequate supply of nitrogen (N) is needed. Nitrogen is a vital nutrient that significantly influences rice growth, development, and yield (Jahan et al., 2020). Effective nitrogen management is crucial for optimizing rice production while minimizing environmental impacts. (Rao and Das, 2023). The most obvious and commonly seen symptom of N deficiency is a reduction in the green color of the leaves (chlorosis), which is generally somewhat evenly distributed throughout the entire leaf. Its deficiency is characterized by low growth rates and stunted plants. Traditionally, nitrogen management in rice cultivation has been based on agronomic practices, such as farmers' experience, soil testing, and crop growth stage-based fertilizer application (Banayo et al., 2018). However, these methods often lack accuracy and fail to explore for dynamic changes in crop nitrogen requirements throughout the growing season (Kivi et al., 2022). Among inorganic sources of N, urea is the most widely used nitrogenous fertilizer in rice because of its high N content and favorable physical properties. The major factor responsible for the low response of crops to fertilizer nitrogen is its low use efficiency, particularly in case of rice crop where it is only 30–40% of applied N due to various N loss mechanisms, namely, surface run-off, ammonia volatilization, leaching and denitrification. Loss of N from soil plant system results from gaseous plant emission, denitrification, surface runoff, volatilization and leaching beyond rooting zones of crops (Pathak, 1999). Cost of remediation of the socio-environmental side effects of N pollution such as global warming, ground water pollution and eutrophication etc. is huge. Hence, enhancing N use efficiency of rice has always been a researchable topic for both the plant nutritionists and environmental scientists. One of the reasons for low N-use efficiency could be inefficient timing of N application and the use of N in excess to crop requirement (Bhatia et al., 2012). The commonly practiced split application of N at specified growth stages of rice and wheat does not offer a very good match of the N supply from applied fertilizer with crop demand because of large variations in crop N requirements and soil N supply (Balasubramanian et al., 2003). In many field situations, more than 60% of applied N is lost because of the lack of synchrony of plant demand with N supply (Singh and Singh, 2003). One-time root zone fertilization (RZF) technique of urea as basal application into 10 cm deep holes positioned at 5 cm apart from the rice roots was found to be able to reducefertilizer-N loss by 56.3–81.9% as compared to surface broad casting of urea (Liu, 2016).

Synchronization of N supply with that of crop N demand is the key for enhancing N use efficiency of crop. Crop-based approaches for in-season N management are now becoming widely available, ranging from simple tools such as a Leaf Colour Chart to sophisticated chlorophyll meters and optical sensors. Application of the N fertilizer based on the concept of SSNM rather than following traditional farming practices resulted in an increase in N-use efficiency by 30–40% and grain yield by 7% in irrigated rice fields in Asia. Leaf colour chart (LCC) is being widely tested and promoted as an easy to use, economical and farmer's friendly diagnostic tool for real time N application. Customized leaf colour chart (CLCC) based N application enhanced yield by 10.3 to 13.3% and 9.9 to 10.9% over conventionally applied urea in direct seeded rice and transplanted rice, respectively. It aims to sustain the productivity of rice-based cropping systems and increase the net income of farmers in India. With the advent of super rice with higher yield potential, high protein rice, bio-fortified rice and climate resilient rice, the concept of 4R based N management stewardship is likely to be subjected to a sea change. Ecological intensification based N management is an area of research recently being focused to bring a holistic approach in N management. Screening and development of germplasm for higher nutrient use efficiency and development of low N input based management options for difficult ecology is another area of research.

3. What is Leaf Colour Chart?

The leaf color chart (LCC) was first developed in Japan, and then researchers from the Zhejiang-China Agricultural University developed a better LCC and calibrated it for indica rice, japonica and hybrids. This tool later became a model for LCC which was distributed by the Crop Resources and Management Network (CREMNET)-IRRI for rice plants; a tool that is simple, easy to use, and inexpensive to determine the time of N fertilization in rice plants. LCC is a suitable tool to optimize the use of N, with various sources of N fertilizer; organic-fertilizer, bio-fertilizer or chemical fertilizer. A leaf color chart is used to measure green color intensity of rice leaves, serves as a cheaper tool to assess the nitrogen requirements by non destructive method (Nachimuthu et al., 2007). Being a standardized chlorophyll meter, the LCC can be compared with the chlorophyll meter to determine their relative accuracy of assessing the leaf status (Anonymous, 2005). Leaf color chart (LCC) as shown in Figure 1 is made of high quality plastic material (8×3 inches) (Singh, 2008). It consist of six color shades ranging from light yellowish green (No: 1) to dark green (No: 6) color strips fabricated with veins resembling those of rice leaves (Nachimuthu et al, 2007); and (Ramanathan et al., 2003). IRRI's standard version ensures that the colors of the paddy leaves can be matched with corresponding LCC colors. The standard version having four green color variations as represented from two for yellowish green to five for the dark green is shown in Figure 1 and 2 (Islam et al., 2020). The LCC is a multipurpose tool that can be used regardless of the nitrogen source applied, including inorganic, organic, or biofertilizers. It facilitates the measurement of canopy greenness along with the green color of individual leaves (Gill et al., 2023). Continuous monitoring and adjustment of nitrogen application based on LCC readings can significantly contribute to improved nitrogen use efficiency and sustainable rice production (Cowan et al., 2021).

Table 1 serves as a practical tool for interpreting the Leaf Color Chart, utilized to assess nitrogen levels in crop leaves (Padariya and Patel, 2024).

Figure 1: Original leaf color chart

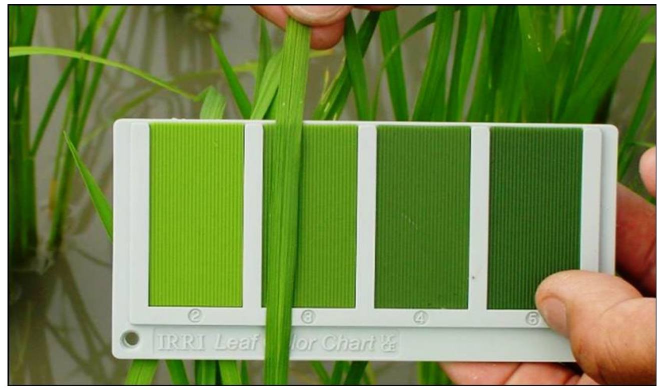

Figure 2: A standardized leaf color chart for assessing leaf N status, IRRI (2020)

4. Advantages of LCC

Leaf nitrogen concentration (LNC) is highly interrelated with chlorophyll content of leaf. There are several devices like leaf colour chart (LCC), SPAD, at LEAF+ of chlorophyll or nitrogen to measure. But as these devices are costly and also unavailable with farmers LCC offers hope to the farmers for measuring plant N necessity in definite time for efficient fertilizer use and improved rice yields (Bhupenchandra et al., 2021). The LCC method offers several advantages, including simplicity, cost-effectiveness, non-destructive sampling, and real-time monitoring of crop nitrogen status (Oláh et al., 2022).

Monitoring plant nitrogen status is important in improving the balance between crop N demand and N supply from soil and applied fertilizers (Cassman et al., 1994). Leaf color is an indicator that is useful for the N fertilizer needs of rice plants. Leaves that are pale or yellowish green indicate that the plant lacks N (Wahiddin et al., 2020). As leaf N content is closely related to photosynthetic rate (Peng et al., 1995) and biomass production (Kropff et al., 1993) it is a sensitive indicator of the dynamic changes in crop N demand within a short season. The LCC is basically a guideline to supply the necessary amount of nitrogen fertilizer which is optimal for achieving maximum yield. The direct measurement of leaf N concentration by laboratory procedure is laborious, time consuming and costly. Such procedures have limited use as a diagnostic tool for optimizing N topdressing because of the extensive time delay between sampling and obtaining results (Yang et al., 2003). A small portable chlorophyll meter could make instant non

Table 1: Leaf color chart for nitrogen management in crops

Colour index	Colour representation	Nitrogen level	Significance	Recommendation
1	Light green	Low	Nitrogen deficiency	Increase nitrogen application
2	Medium light green	Slightly low	Mild deficiency	Slightly increase nitrogen application
3	Medium green	Adequate	Optimal for growth	Maintain current nitrogen application
4	Dark green	High	Excess nitrogen	Reduce nitrogen application
5	Very dark green	Very high	Potential toxicity	Significantly reduce nitrogen application

destructive and quick chlorophyll readings of plant leaves for estimating the chlorophyll content (Watanabe et al., 1980). Because chlorophyll content in a leaf is closely correlated with leaf N concentration (Blackmer and Schepers, 1994; Evans, 1983), the measurement of chlorophyll provides an indirect assessment of leaf N status. The high price of SPAD limits its use by individual income-poor farmers (Balasubramanian et al., 2003). So instead of this costly device another simple, quick and nondestructive tool for estimating leaf N status is Leaf Colour Chart (LCC) (Nachimuthu et al., 2007).

The LCC used in Asia are typically a durable plastic strip about 7 cm wide and 13 to 20 cm long, containing four to six panels that range in color from yellowish green to dark green (Hushmandfar and Kimaro, 2011). These include use of a Leaf Color Chart (LCC), which relies on visual comparison between leaf color and a color chart to assess the N status of certain plants (Ali et al., 2012). By comparing the leaf color with a standardized color chart, farmers and agronomists can make informed decisions regarding nitrogen fertilizer application rates and timings (Golicz et al., 2021). The user needs to match the middle part of rice leaf with its corresponding color strip on panel which provides the LCC reading and approximate nitrogen fertilizers to apply to the fields. It is a simple-to-use and inexpensive and can even help farmers who are not highly trained in making nitrogen applications. Inexpensive leaf color chart (LCC) has proved quick and reliable tool to decide the time when fertilizer needs to be applied to the crop (Singh, 2008). In practice, leaf color is compared with its corresponding color in LCC inside body shade with proper lighting conditions. Integrating LCC data into existing nutrient management decision support systems can enhance their accuracy and precision (Gorai et al., 2021). Conducting comprehensive economic and environmental assessments of LCC-based nitrogen management can provide insights into the cost-effectiveness, profitability, and sustainability aspects (Falcone et al., 2016)

Currently, the leaf color comparison process with LCC is manual i.e. farmers have to place paddy leaves on the shades of LCC and match it by simply visualizing. Thus, accurate measurement process is difficult for them (Islam et al., 2020). The farmers are also required to compare 6 to 10 leaves with the LCC level and find the average values. If the average value of Aman paddy leaf color level is less than or equal to 3.5 LCC level, nitrogen fertilizer is required of 7.5 kg per 0.133 hectares of land (Anonymous, 2020). Usually, this process lacks the ease of detecting the accurate amount of fertilizers due to assumption. With the use of LCC for paddy, there is a possibility of saving fertilizers which may cause a positive environmental effect.

Incorporation of LCC with precision agriculture technologies, such as remote sensing, unmanned aerial vehicles (UAVs), and satellite imagery, can improve the spatial and temporal monitoring of rice crops. This incorporation can give real-time information on nitrogen status, enabling site-specific nitrogen management and timely interventions (Pedersen and Lind, 2017).

5. Research Findings on Use of Leaf Color Chart for Nitrogen Management

Several research works have been carried out throughout the world for nitrogen recommendation in rice crop through LCC. One of the key features of site specific nutrient management is dynamic adjustment of fertilizer N using gadgets such as leaf color charts (LCC) and chlorophyll meters (Singh et al., 2012). leaf color chart (LCC) is an easy technique to use and cost effective apparatus for monitoring chlorophyll of leaf and improving nitrogen fertilizer management in transplanted rice (Iqbal et al., 2016). According to (Nachimuthu et al., 2007) under the similar soil type (clay) and climatic conditions (tropical) in South India, a farmer who can afford higher fertilizer cost could adopt LCC cv 5 @ 30 kg N ha^{-1} each time to get the highest yield and net return and a farmer with low resource allocative efficiency could adopt LCC cv 4 at the rate of 20 kg N ha^{-1} each time to get a yield comparable to that of the blanket N with a saving of 50% nitrogen. LCC based N application at critical stages in ADT 36 rice varieties during kuruvai season result in saving of 15 kg N ha^{-1} as compared to the blanket recommendation of 120 kg N ha^{-1}. LCC-N management during Thaladi season for ASD 18 revealed that LCC measurement at critical growth stages resulted in the conservation of 70 kg N ha^{-1} compared to the blanket N of 150 kg N ha^{-1} in three splits (Thiyagarajan et al., 2000). Average saving in N was 25 kg ha^{-1} by using LCC method without any reduction in yield (Balasubramanian, 2002). LCC at 14 days interval or at critical growth stages of active tillering, panicle initiation and 10 days after of active tillering and PI would save 40% of N as compared to blanket recommendation (Hussain et al., 2005). Higher nitrogen use efficiency of LCC based N management over blanked was reported by Maity and Das (2006). Chandrashekara (2009) reported that the application of 50 and 60 kg N ha^{-1} dressing^{-1} coupled with LCC threshold 6 recorded higher cane yield (150.5 and 151.7 t ha^{-1} during I season and 123.8 and 125.0 t ha^{-1} during II season, respectively), CCS yield, juice, brix, pol and lesser reducing sugars, total N, P and K uptake than conventional practice.

Leaf colour chart based N management reduced the N fertilizer use by 29 kg ha^{-1} and it also reduced the lodging, pest incidence and production cost of rice (Nguyen Nogoc De and Le HuuHai, 1999). LCC based N management is suggested to be the optimal N fertilization strategy for rice, since it gives higher yields besides effecting saving of N as compared to blanket N recommendation or the soil-test based N recommendation under field specific situation. With the help of LCC and SPAD, N could be saved up to 50 and 60 kg ha^{-1}, respectively without yield decrement Maiti (2003). Maiti et al. (2004) reported the mean values of LCC and SPAD varied from 3.19–5.31 and 27.36–39.26, respectively, in rice. The results showed that the amount of N can be saved as 20–42.5 and 27.5–47.5 kg N ha^{-1}

through the use of LCC and SPAD in rice over the fixed-timing N treatment T7 where 150 kg N ha^{-1} was applied in three 3 splits without reduction in the yield. Hussain et al. (2005) reported that in rice the nitrogen applied by studying the LCC value at 14 days after panicle initiation and 10 days after panicle initiation would save 40 per cent of N as compared to blanket recommendation. Shukla et al*.* (2006) found that NUE can be increased using LCC-based N management without basal N application, provided indigenous soil N supply is sufficiently high (50–60 kg N ha^{-1}). Shukla et al. (2004) reported a threshold LCC value of 4 for an inbred line (Saket 4) for an optimal yield and NUE in the western Indo-Gangetic plains of India. Samson et al. (2005) from the field experiments conducted at IRRI and PhilRice (Philippines), where real-time N management through LCC in the dry season was carried out, reduced the N fertilizer use by 45 to 80% compared to the conventional N management with a fixed seasonal N rate of 210 kg N ha^{-1}, while achieving comparable or higher yields of 6–8 t ha^{-1}. Nitrogen concentration in fully expanded youngest leaf correlated significantly (p< 0.01) and positively with LCC score at tillering, panicle initiation, and flowering for two years. The critical LCC score obtained was at tillering, at panicle initiation 4.4 and at flowering 4.5 (Mahajan et al., 2014). Iqbal (2016) revealed that LCC technique can save 40% urea without any loss of yield compared to farmer's practice. They opined that corrective N application should be done when observed leaf N indicator values at a particular growth stage reach or go below the critical values. Two microcosm experiments in the Mekong Delta of Vietnam in 2018 using eight treatments of N-fertilizer application were conducted by Minamikawa et al. (2019) to evaluate the feasibility of variable-timing, fixed-rate application of cattle biogas effluent using a leaf color chart (LCC) for rice (*Oryza sativa* L.) and to determine the optimum LCC threshold for grain yield. Results revealed that rice yield tended to increase with increasing LCC threshold. There was a positive linear relationship between LCC and chlorophyll content (SPAD) values (R^2=0.73–0.79). Grain yield was well explained (R^2=0.70–0.89) by the seasonal mean LCC or SPAD value. Plant total N uptake increased with increasing LCC threshold, but the three calculated indices of N use efficiency (NUE)-apparent N recovery, agronomic NUE, and internal NUE-were not always improved with a higher LCC threshold. Results showed that the tested variable-timing, fixed-rate strategy for the application of cattle biogas effluent was feasible and the optimum LCC threshold for grain production was 3.75 under the prevailing microcosm conditions.These studies indicated that for the crop need-based N management using LCC was equally good for inbred and hybrid rice varieties to maximize their yield and N fertilizer use efficiency (Satput et al., 2014).

These tools can automate LCC scoring, store historical data, provide real-time recommendations for nitrogen top dressing, and enable data sharing among farmers, extension workers, and researchers (Capossele et al., 2018).

Now a day, IoT technology is incorporated with the Leaf Colour Chart which indicates a notable progression in agricultural technology, offering the prospective to boost crop management techniques and support sustainable agriculture endeavors (Padariya and Patel, 2024).

6. Disadvantage of LCC

Major disadvantage of this approach is being subjective to the viewer's eye acuity variant to sunlight, environmental factors and biological age of the person. The problem in this LCC is that the tool is still manual and the assessment / classification process is carried out using color estimates based on eye sight. The LCC method relies on visual assessment of leaf color as an indicator of plant nitrogen status (Tao et al., 2020). This creates uncertainty because everyone has different estimates. Farmers have to place paddy leaves on the shades of LCC and match it by simply visualizing. Thus, accurate measurement process is difficult for them. The farmers are also required to compare 6 to 10 leaves with the LCC level and find the average values. Usually, this process lacks the ease of detecting the accurate amount of fertilizers due to assumption. Based on these problems, it is necessary to have an automatic classification system of rice leaf color that can help farmers in determining the category of rice plants based on LCC.

7. Automated Method Used for Measurement of Nitrogen Adequacy based on Leaf Color Chart (LCC) in Rice

As the LCC is still manual and the assessment/classification process is carried out using color estimates based on eye sight, this creates uncertainty because everyone has different estimates. Based on these problems, it is necessary to have an automatic classification system of rice leaf color that can help farmers in determining the category of rice plants based on LCC. In a study carried out by Wahiddin et al. (2020), the color classification system of rice leaf images was carried out by extracting RGB (Red, Green, Blue) image features of rice leaf images. While the classification process is done by finding the color similarity between the images of rice leaves with the LCC scale using the Euclidean Distance method. The results obtained from the color classification system of rice leaves in this study have an accuracy rate of 75%.

Here feature extraction is the process by which certain interesting features in an image are detected and represented for further processing. This is an important step in computer vision and digital image processing (digital image processing) solutions because it marks the transition to pictorial to alphanumeric data representation. The resulting representation can then be used as input for pattern recognition and classification techniques (Marques, 2011). The method of classification of nitrogen adequacy based on Leaf Color Chart (LCC) in rice crop through Color Feature Extraction and Euclidean Distance measurement given by Wahiddin et al. (2020) is summarized as follows:

A. Image capture

a. Choose the picture of rice leaves to be categorized in color

B. Pre-Processing

a. The selected rice leaf image will go by the pre-processing stage, which is to change the image size to (233 x 1297) pixels. The size is adjusted to the color image in the training data.

b. The image that has passed the resizing process will be displayed in the application complete with the location / path where the image is stored on the computer system used.

C. Selection of training data

a. Select the folder where the LCC imagery will be stored as a reference for the color classification of rice leaves.

b. The color image in the folder consists of 4 colors with size 233×297 pixels

D. Feature Extractions

a. The image features to be extracted are the Green (G) color features

E. Color classification

a. The color classification process is done using the Euclidean Distance method.

b. The value calculated by the Euclidean Distance formula is the average value of the colors of the images of the rice and all the images of the training data.

c. The smallest euclidean distance value is considered to have the highest similarity/degree of similarity.

Classification of paddy leaves into four categories of LCC color is the principal step. Therefore, in another automated method of nitrogen measurement of rice leaf, Islam et al. (2020) considered manually comparing LCC as their research problem and wanted to address it by using CNN (Convolutional Neural Network) and DT (Decision Tree) classifier as two proposed automated methods. Color classification can be performed by Convolutional Neural Network as well as other Machine Learning (ML) algorithms. According to them these two methods can be integrated through a mobile app and thus a smart farming system can be introduced. Hence, by automating the fertilizer recommendation system can help farmers use fertilizers efficiently. This can make a great change over the total economy of a country. Accurate color level prediction of paddy leaf into 4 categories of LCC can be a fruitful way of this research (Islam et al., 2020). Automatic prediction of leaf color level by using digital image processing techniques has been proposed by Singh and Singh (2015). Here, test images are compared with database generated LCC value and then the color level is predicted. Color histogram analysis and pixels Bitwise operations have been proposed for paddy leaf color perception with standard LCC color level (John et al., 2012). However, the machine learning and the Deep Neural Network based algorithm may bring more accurate results (Islam et al., 2020).

Data acquisition technique from the field is one of the momentous phases of this research. There are some constraints for capturing images which is proposed by IRRI. The farmers need to capture images inside the body shade with proper lighting conditions (Anonymous, 2020). Some researchers have used white paper as a background for better segmentation and prepossessing (Singh and Singh, 2015). Accurate segmentation depends on the proper data acquisition process. Some researchers have embedded Otsu's method in mobile application to obtain threshold values where the leaf will be segmented as object pixels from background pixels (Prilianti et al., 2015). The background pixels are the area with white paper and object pixels are the area of the leaf portion. Reducing the limitation of removing background, Islam et al., 2020 used the DeepLabV3+ segmentation model which is invented by Google. Moreover, it can segment Regions of Interest (ROI) pixels from the leaf whatever the background is (Chen et al., 2018).

From those color classification architectures and ML algorithms, Islam et al. (2020) designed their own optimal model structure for paddy leaf color classification with the best result. The main aim of this study is to propose a suitable method for automatic categorization of paddy leaves using their digital images. The color of the paddy leaf depends on the maturity as well as Nitrogen concentration. However, Nitrogen concentration can determine by analysing only the top most leaves. At first, a total of 560 top most paddy leaf images were taken. The resolution of the images were 500×500 pixels and by using in Nokia 3 (8MP Camera) and Samsung S8 (12MP Camera) devices for collecting data. Moreover, the color of the paddy leaf depends on the ambient light. Therefore, those images are captured in the natural daylight condition inside the body shade which condition is proposed by IRRI. At the time of data collection, the LCC data acquisition procedure was maintained as well as classified each images comparing to LCC stage and carefully labeled total data set corresponding to the LCC level with the help of domain experts. If the color of a paddy leaf is yellowish green, this color corresponds to LCC level 2. On the other hand, if the color of a paddy leaf is dark green, this color corresponds to LCC level 5. The middle 2 levels of the LCC is between the colors yellowish green and dark green and all these four types of paddy leaves are shown in Figure 3. Those four paddy leaf color levels reflect the nitrogen concentration of crops. The leaf color level 2 and 3 represent that the crops need fertilizers. The fertilizer is not needed for leaf color level 4 and level 5 as the nitrogen

Figure 3: Four LCC level of paddy leaf

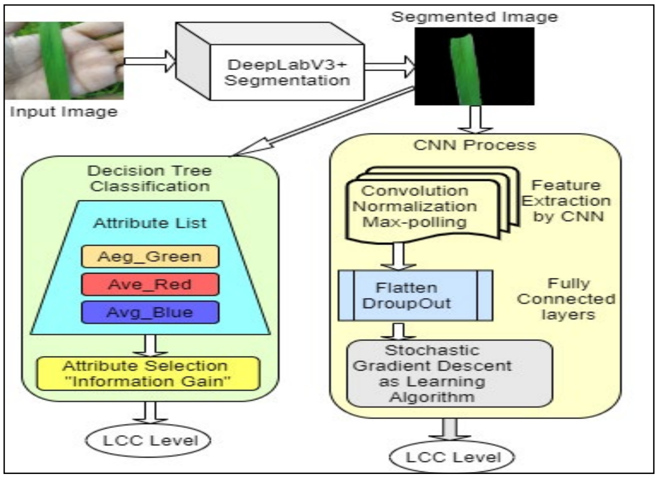

Figure 4: Proposed two methods

concentration is maximum in those two color level. At first, images of paddy leaves are taken as inputs. After that the DeepLabV3+ semantic segmentation is performed for background removing. The segmented images are used for both the CNN method and the DT method. In the DT method three features are extracted from segmented images. In both methods, the output is the LCC level. The entire flow diagram the work is depicted in the Figure 4.

In this work, attention is given mainly to transform the manual reading of LCC level to an automated method that could be easily deployed in smartphones. Entire work is summarized by three main steps: (1) segmentation, (2) feature extraction, and (3) training and classification. These approaches are performed by using DeepLabV3+ and Convolutional Neural Network. Reducing the sunlight illumination problem while data acquisition can bring out a revolutionary change in this filed. The DeepLabV3+ process can be integrated in Mobile Phone by using the MobileNetV2 backbone network with TensorFlow. This fruitful solution can also be implemented for other crops like soybean and wheat for nitrogen fertilizer recommendation. Moreover, two improved algorithms have also been implemented that accurately classify the Aman paddy leaf according to LCC level with the best 94.22% accuracy in the CNN method and 91.22% in the Decision Tree method. This automated method of LCC will help the farmer and recommend need based nitrogen fertilizers. The implementation of this system in smart devices will monitor the paddy field automatically that is fruitful for rural area farmers. The farmer will not need manual process to detect the nitrogen level and measuring out the exact amount of fertilizers.

8. Conclusion

Among the automated methods of measuring nitrogen adequacy in rice leaf, LCC helps in need based nitrogen fertilizers requirement in paddy. Creating digital tools and mobile applications that leverage LCC data can simplify data collection, analysis, and interpretation. The implementation of this system in smart devices will facilitate in monitoring paddy field by the farmers automatically avoiding the process of manual nitrogen level detection and also knowing the exact amount of fertilizers required for optimum crop growth for maximum yield.

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