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Leaf color chart (LCC): An instant tool for assessing nitrogen content in plant: A review

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Abstract
Nitrogen (N) fertilizer carves a lion's share amongst the nutrient source required for plant growth and development. Fertilizer N is touted as one of the key inputs in cereals, in particular rice production in Asian countries. Amongst the nutrient management techniques, N management is the main concern in rice production. N holds a distinctive prominence amongst the nutrient elements and is the "mineral of life" for rice. It is the utmost needed input that restricts rice production in irrigated environment. There is no conciliation on the requirement for the efficient use of N fertilizer for augmenting rice production though the price of N fertilizers escalates with time. The leaf nitrogen concentration (LNC) is highly correlated with chlorophyll content. To measure it, there are many devices like leaf colour chart (LCC), SPAD, at LEAF^{+} of chlorophyll or nitrogen. As these devices are cost effective and unavailable with all farmers, LCC provides prospects to the farmers for estimating plant N requirement in actual time for effective fertilizer use and augmented rice yields.

Keywords: Nitrogen, chlorophyll, colour, fertilizers and leaves

Introduction

Assessing the plant N content is vital to improve the equilibrium amid crop N requirement and N sourcing from topsoil and added fertilizer since the leaf N status is correlated to photosynthetic rate (Peng *et al*., 1995) [23] and biomass production. N is the utmost extensively used fertilizer in cereals and its intake has augmented noticeably in the recent years (FAOSTAT, 2009) [10]. Cereals occupied greater than half of the entire N use in the world. It was estimated that fifty to seventy per cent additional cereals shall be needed by after 20 years to nourish more than 90 crore world populace which shall entail the need for fertilizer N at larger quantum nevertheless the N retrieval efficacy in crops is enhanced. There are reports that only a meagre N recovery efficiency of thirty to fifty per cent and not exceeding even per cent by the succeeding crops (Ladha *et al*., 2005) [14]. Unfortunately, N use efficacy resulting blanket N addition was testified as low as thirty per cent in rice–wheat cropping system (Krupnik *et al*., 2004) [13]. The vital cause for stumpy N use efficacy is an ineffective application of split N doses in surplus of crop necessities. When used ineffectually, anenormous portion of the applied N is wasted through leaching and denitrification. N is touted as the utmost significant nutrient required for crop sowing to its crucial role in photosynthetic pigments manufacture, necessary for the photosynthesis procedure which regulates photosynthetic activities and primary functions (Curran *et al*., 1990) [4]. The crop production in the world augmented considerably owing to the usage of nitrogenous fertilizer (Peng, 2010) [19]. N status of leaves can be indirectly assessed on chlorophyll status since the majority of the leaf nitrogen is assimilated in chlorophyll (Moran *et al*. 2000) [16]. Chlorophyll status is correlated to leaf nitrogen status was also reported by Evans, 1983, the nitrogen content of crop can be accessed through physical examination of its leaf colour. The direct quantification of leaf N status via laboratory techniques is tedious and expensive. This technique have restricted usage as analytical device for improving N top dressing due to the wide-ranging time interval amid sampling and finding results virtually with the introduction of high yielding varieties (HYV), managing N seems to be the top priority for exploiting genetic yield potentiality of the HYV. Nevertheless, farmers use to apply fertilizer N unsystematically in the pursuit of hankering bumper yields of rice. Up till now, mostly N is applied in rice without any site specific recommendation nor any prior soil testing ensuing nutrient deficiencies and toxicities. Evidently, harmful effect of inappropriate N fertilization on conservation of soil quality has been rigorously depleted soil quality and its nutrient reserve, concomitantly disturbing the dynamic stability in soil-plant-environment continuum. Nevertheless, such malpractice inflicts stark hazard to the environmental sustainability, even distorting the biodiversity and subvert the quality of ground water. Such detrimental magnitudes warrant us preventing observance to haphazard N fertilizer appliance in rice cultivation; in its place, it asserts us to balance the stability in the ecosystem viasuitable N supervision. In India, paddy is grown in 44.5 million hectares with an output of 172.58 million tons and throughput of 3878.2 kg ha^{-1} (FAO Stat., 2018) [8]. To afford sufficient food and nutrition to the worldwide populace is estimated to touch 9 billion by 2050, rice yields requisites to be increased by at least 60 per cent (FAO, 2009) [9]. In 2014, global production of rice exceeded 740 Mt, of which 90 per cent was documented in Asia (FAOSTAT, 2016). In various field conditions of north western India more than 60 per cent of applied N is lost because of the lack of synchrony of plant demand with N supply. The N nutrients present in almost all soil are insufficient for crop needs, therefore, additional N must be given to maintain or increase yields. Of all the nutrients supplied to the soil, so far N fertilization has the most influence in increasing crop production (Wahiddin *et al*., 2020) [21]. 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. The common fertilizer N commendation does not consider site to- site deviation in N supply ability of soils to fulfil the crop needs. Fulfilling the N supply with crop need will improve N use efficacy and lessen N losses to the surroundings. Therefore, there is an impetus for managing fertilizer N more proficiently with reference to the real demands of crops so as to enable a major portion of N is effectively assimilated in grain yield.

Use of leaf colour to control the scheduling of N appliance in rice, IRRI, Phillipines has inducted a plant-based decision tool, the leaf colour chart. LCC is a good quality plastic strip with diverse shades of green colour which ranged from light yellowish green to deep green. The leaf colour chart (LCC) was the first time introduced in the agricultural sector of the world by scientists of Japan (Furuya, 1987) [11]. Standard leaf colour chart (LCC) is an available tool that is used as a reference to estimate leaf colour and nitrogen content (Yang *et al*., 2003) [23]. The LCC is a modest and economical diagnostic tool for estimating green colour intensity of plant leaves especially cereals leaves to evaluate the N necessities by non-destructive technique (Nchimuthu *et al*., 2007) [17]. 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. The Leaf Colour Chart (LCC) is used to determine the N fertilizer needs of rice crops. It determines the greenness of the rice leaf, which indicates its N content. It is significant device that allows farmer to regulate the N fertilizer appliance considering the crop requirement (Ali *et al*., 2012; Witt *et al*., 2005) [2]. It is prepared by excellent quality plastic material with a dimension of 8×3 inches (Singh, 2008) [20]. Chinese investigators at ZAU, Hangzhou established a LCC with scale of 8 green colour shades (3, 4, 5, 5.5, 6, 6.5, 7 and 8) and it was adjusted rice varieties (Yang *et al*., 2003) [23]. Similarly, scientists at the UC, Davis established 8-panel LCC with scale of 8 green colour shades (1–8). Lately, scientists at IRRI have advanced the colour panels of the IRRI-LCC to match the spectral reflectance of cropleaves and a 4-panel IRRI-LCC (4 green colour shades from 2 to 5) were encouraged from 2003 (Fairhurst *et al*. 2007) [6]. They designed it for evaluating the chlorophyll development and its content in crops. Various research findings have help to prove that it is essential for determining nitrogen deficiency and ameliorating its negative impact. Thus LCC can be considered as principle and inexpensive device to improve utilization of N in paddy. The leaf colour chart gives a precise results in determining deficiency of N in crops in a similar manner like ameasuring device for chlorophyll estimation which shows accurate results (IRRI, 2003) [23] at the same time diagnosing of N inadequacy (Mohanty *et al*., 2013) [15]. Leaf colour chart is useful for supplying fertilizers sufficiently as per the requirement and at proper time (Witt *et al*., 2005) [22]. The LCC is an accessible as well as a cheaper analytical device to monitor the analogous greenness of a paddy leaf which will indicate the N stature of the plant. The LCC may have four to six colours which depend on the producer and the colour which may vary from yellowish to dark greenish a like luxuriant green colour of foliage; individual colour is different from each other. The pace of photosynthesis and biomass accumulation is strongly adhered with foliar N stature of paddy which also acts an important sign of change in plant N requirement during their growing period. As LCC is proved to an effective device to quickly measure the foliar N stature thus it can direct the appliance of nitrogenous fertilizerso as to sustain an adequate foliar N content, subsequently which is essential for enhancing paddy productivity alongside adequate management of nitrogenous fertilization. A chlorophyll meter gives a quick (without damaging the leaf) method for determining foliar N availability, however it is expensive thus preventing its accessibility to the farmers therefore, LCC is a cheaper and user-friendly option. Generally, LCC is made up of plastic, rectangular in shape stripe with five or more panels, which may ranges in colour from yellowish green to dark green. Various kinds of LCCs with different shades of colour were produced and disseminated to paddy farmers thus creating a confusion concerning the type of LCC to be used. These leads to the requirement of a reliable LCC which may act as a bench mark to cross calibrate the threshold values amongst LCCs. The systemized LCC (Fig1) is five inches in length, composed of best quality plastic, with five colour shades from yellowish green to dark green which are made-up with veins similar to paddy leaves.

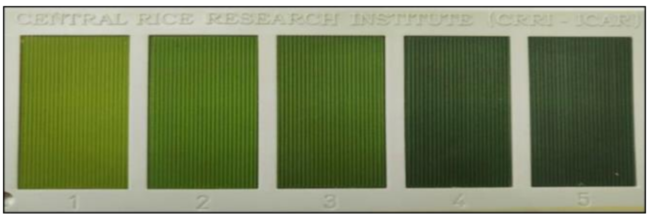

Fig 1: Different Swap of 5-panel LCC from (1) to (5) (IRRI, 2005)

The photos (Fig.2) and LCC colour index (Fig. 3) demonstrate the application of the systematized LCC to measure nitrogen stature of leaf and the amendment N appliance to paddy. In picture (a) plants with no nitrogenous fertilizers is having yellowish colour leaf. Insufficiency of nitrogen is established in picture (b) the LCC value lays in-between panels 2 & 3. At lower rates fertilizer N in pictures (c) and (d) the crops appear to be better, however the lower LCC value still highlights an N deficiency conditions. At elevated dose of nitrogenous fertilization in pictures (e) and (f) the crops appear well established and the canopy is also closed. The LCC value lies in- between panels 3 and 4, which is acrucial range for almost all the transplanted paddy. In pictures (g) and (h) crops with a high rate of nitrogenous fertilizers were dark green in colour. Foliage shade is deeper than the LCC panel no. 4 signifying a superfluous of nitrogenous fertilizer. Use LCC values of 10 leaves to calculate average value and if the value is higher or lower than 3, it indicates the requirement of nitrogen fertilization (top dressing).

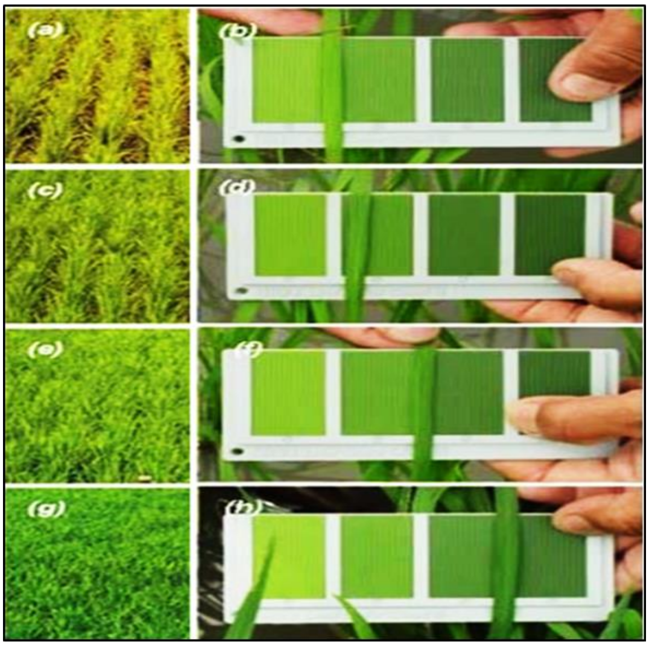

Fig 2: Use of the standardized LCC to assess leaf N status in crop (Mohanty *et al*., 2013) [15]

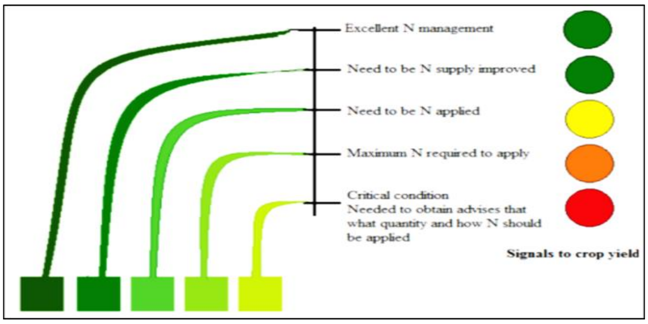

Fig 3: LCC colors index for nitrogen application (Mohanty *et al*., 2013) [15]

Recent development in use of modern tools in compliance to LCC

Through the advancement of scientific knowledge, several scientists resorted to use of computer for analyzing the nutrients status of crops (Patrício and Rieder, 2018) [18]. Agarwal and Dutta (2018) [1] executed multivariate data analysis and linear regression on leaf images to interpret chlorophyll status in spinach. Likewise, Chung *et al*. (2018) [3] adopt the use of the smart phones camera to discover neat infrared colour to identify plant stress. Tao (2020) developed a smart phone-based recognition of leaf colour levels in paddy. It is implicit to know that there is a linkage between the leaf colour and its nitrogenous status, therefore, identification of nitrogen status in paddy leaves is essential for advising farmers during application of fertilizer. However, the finding of existing methodology extremely relies on the field ecological circumstance and these techniques involve particular imaging and computing tools. To solve these issues, a smart phone application was introduced base on a typical leaf colour chart (LCC) to identify the colour levels of paddy leaves (Fig. 5). With the help of this application, successful identification of regions of paddy leaf as well as LCC value in a photograph was done, by the colour threshold segmentation. The colour descriptions of each region were successfully calculated via CIELAB histograms.

Fig 4: The 4-panel leaf gripper with LCC

Fig 5: Image taking on the LCC and a leaf in a rice field (Tao *et al*., 2020)

Potential savings in urea through the LCC technique

The application of LCC in irrigated situation has been reported to save 23 kg N(50 kg Urea/ha) (Fig. 6). The calculated annual savings of urea are enlisted and evaluated in the table below for some of the countries. In India the estimated saving of urea is 834,000 tons if 50 per cent of farmers resort to LCC in the irrigated rice area of 22.3 m ha. Apart from India, Bangladesh Vietnam, Indonesia, Thailand and Philippines are successfully adopting LCC.

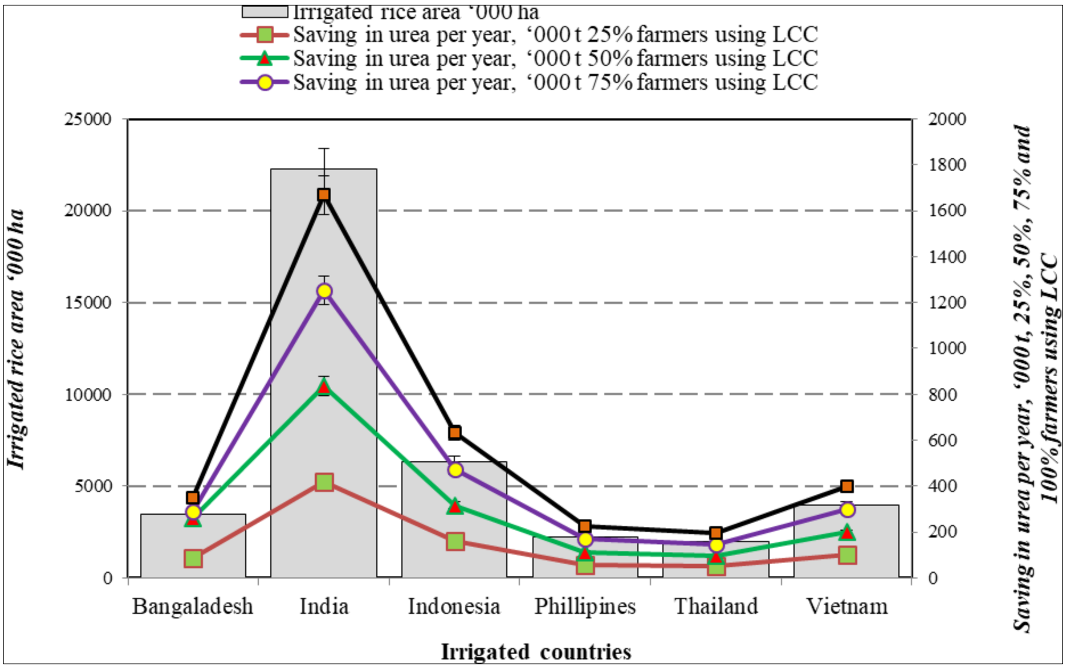

Fig 6: Depiction of urea savings through the LCC technique

Vertical bars represented the standard error
(Adopted and sourced from Nitrogen parameters, https://www.nitrogenparameters.com/index.html)

Merits of LCC

- LCC is anuncomplicated and effortless tool for the farmers to measure nitrogen status of the leaf and to identify the instance for top dressing of N to paddy.
- LCC is cheap and portable thus, making it easy to carry to field for estimating N status of the leaf.
- It is a non-destructive method and doesn't involve any laboratory analysis.
- Any specific knowledge or skill is not require for using LCC because it depends only in comparing the colour and computing the scale of the leaf with standard chart.

Demerits of LCC

- LCC fail to specify minor variations in leaf greenness as the colour shades lies in between two shades.
- The comparative accurateness of LCC to measure the leaf N status can be estimated only when it is equated and interrelated with chlorophyll meter readings and adjusted accurately with the plant groups.
- LCC is resorted only to adjust the top dressed N but fail to adopt the basal N appliance by LCC.
- LCC can be better suited in site-specific nutrient management approach wherein to realise optimal reaction to N fertilizer, other nutrients need not be restricting.
- Hence, sufficient levels of other nutrients need to apply on basis of soil tests results.
- P or K deficits make dimmer leaf colour leading to inaccurate LCC interpretations.

Conclusion

It is can be inferred that leaf colour chart (LCC) is a stress-free, user friendly and economical tool for assessing chlorophyll content of rice leaf. LCC centric nitrogen supervision aids farmers to assess the actual time N requirement of the crop and guarantees N saving without conceding their production.

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