New Leaf Color Chart for Effective Nitrogen Management in Rice

By C. Witt, J.M.C.A. Pasuquin, R. Mutters, and R.J. Buresh

Leaf color charts (LCC) offer substantial opportunities for farmers to estimate plant nitrogen (N) demand in real time for efficient fertilizer use and high rice yields. We developed a new, standardized LCC for rice in Asia based on the actual colors of rice leaves. The new chart and updated guidelines for its use are promoted in many Asian countries through the Irrigated Rice Research Consortium (IRRC).

Asian farmers generally apply fertilizer N in several split applications, but the number of splits, amount of N applied per split, and the time of applications vary substantially. The apparent flexibility of rice farmers in adjusting the time and amount of fertilizer application offers potential to synchronize N application with the real-time demand of the rice crop.

Improved N management and balanced fertilization are key components of the site-specific nutrient management (SSNM) approach developed by the International Rice Research Institute (IRRI) in partnership with the National Agricultural Research and Extension Systems in Asia. Field studies in major irrigated rice areas have shown significant yield and profit increases with SSNM over typical farmer fertilizer practice (Dobermann et al., 2004). These studies revealed that sub-optimal N management by farmers is a key constraint to increasing yield (**Figure 1**). Improved N management caused greater yield responses to fertilizer N application compared to farmer practice, and yield responses to fertilizer phosphorus (P) and potassium (K) application often only occurred after yields increased through improved N management with SSNM. Leaf color charts are an effective, low-cost tool that can assist farmers in improving their N management, and efforts are underway to promote the technology at wider scale among Asian rice farmers.

Numerous LCC units have been fabricated and distributed to farmers in a number of Asian countries since the 1990s. The most widely used LCC was developed by IRRI in collaboration with

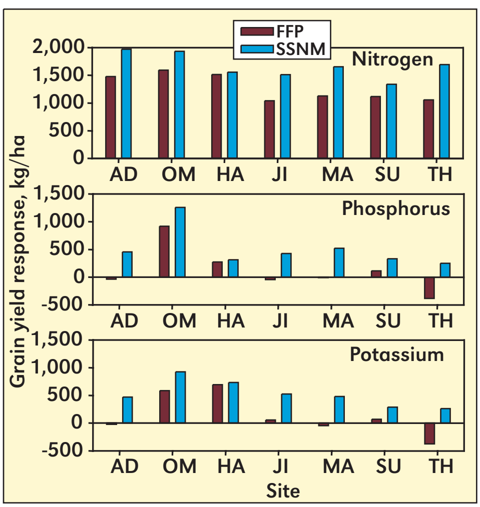
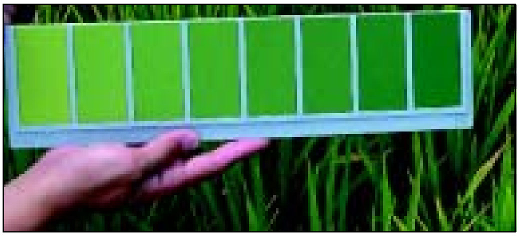


Figure 1. Yield response to fertilizer N, P, and K application following farmer fertilizer practice (FFP) and the SSNM approach on 179 farms at seven key sites with irrigated rice in Asia, 1997-1999. AD = Aduthurai (Tamil Nadu, India), OM = Omon (Cantho, Vietnam), HA = Hanoi (Vietnam), JI = Jinhua (Zhejiang, China), MA = Maligaya (Nueva Ecija, Philippines), SU = Sukamandi (West Java, Indonesia), TH = Thanjavur (Tamil Nadu, India).

Figure 2. The leaf color chart developed by University of California Cooperative Extension (UCCE) for rice in California.



the Philippine Rice Research Institute (Balasubramanian et al., 1998). Fueled by the success of the chart and an increasing demand for quality and low-cost LCCs in Asia, we used an approach developed at the University of California Cooperative Extension (UCCE) to improve and standardize the colors of the LCC. In this approach, a meaningful range of green plastic chips ranging from yellowish green to dark green match the color range of rice leaves that cover a continuum from leaf N deficiency to excessive leaf N content. This approach was first used to develop an LCC for California rice varieties (**Figure 2**). A systematic analysis using a Minolta CM 3700-d spectrophotometer showed that the colors of LCCs available in Asia do not match those of rice leaves (Witt and Pasuquin, unpublished).

We used actual leaf spectral reflectance measurements from a 2-season field experiment in 2001 involving 10 modern rice varieties grown at three different N levels to develop target reflectance patterns for an ideal LCC prototype (Witt et al., 2004). A spectral reflectance pattern describes the composition of light that is reflected from a rice leaf across the whole spectrum of wavelength from blue (400 nm), over green (550 nm) to infrared (700 nm). Based on the target pattern (**Figure 3A**), we worked with the local pigment and plastic industries in the Philippines and produced a standardized chart that captures the relevant range of rice leaf colors in Asia. The new 4-panel LCC is shown in **Figure 4**. We chose only 4 color panels for the LCC because any color outside this range would not be a desirable goal for modern, high yielding varieties in Asia as it would either be a sign of extreme N deficiency or excess supply of N.

The quality of the new 4-panel LCC was evaluated using spectral reflectance (SR) measurements (**Figure 3**). In this analysis, we compared SR patterns of rice and maize leaves with those

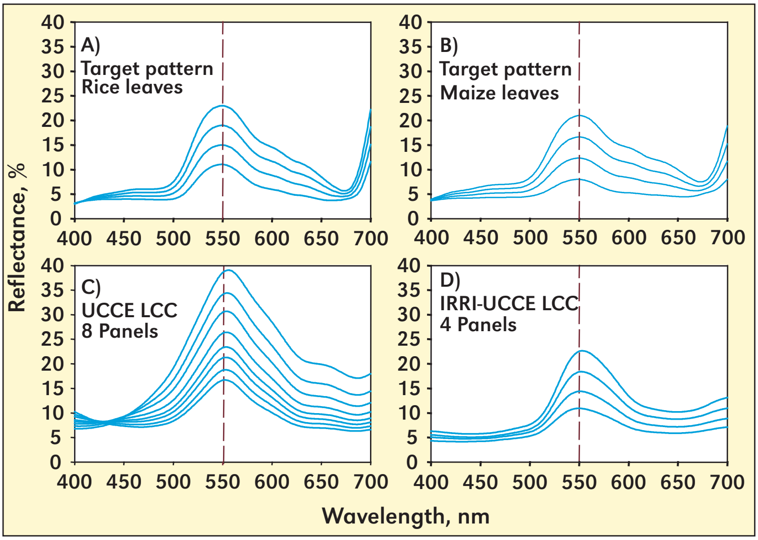


Figure 3. Target spectral reflectance patterns for a theoretical LCC based on actual reflectance measurements performed on leaves of major Asian rice varieties (A) and of a maize variety (B). Actual reflectance patterns for LCCs developed by UCCE for Californian rice varieties (C) and IRRI-UCCE for Asian rice varieties (D). The dotted line at 550 nm (green) reflects the maximum reflectance of actual rice and maize leaves in the visible spectrum. The top line in each chart represents the lightest green, while the lowest line represents the darkest green.

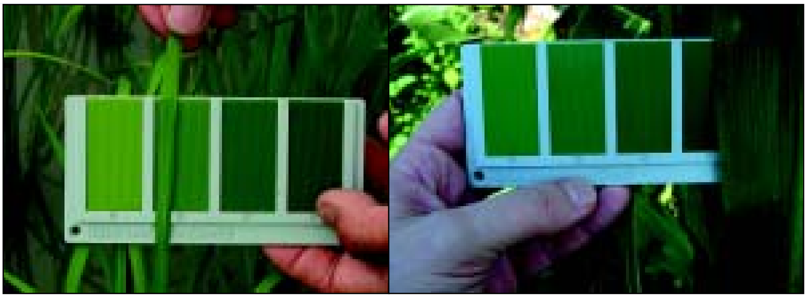
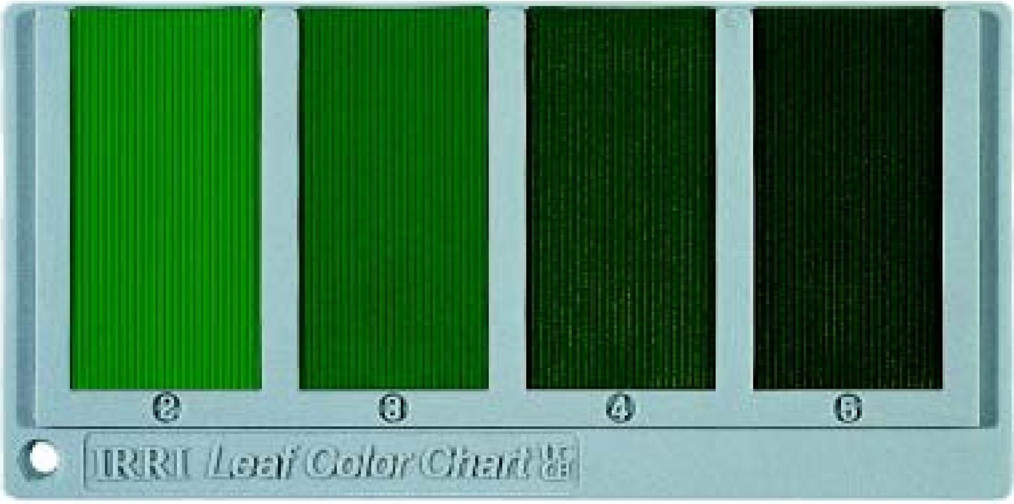


Figure 4. The new 4-panel LCC developed by IRRI in collaboration with UCCE for rice (left). The same chart might also be a useful tool in maize (right).

of the two leaf color charts developed by UCCE and IRRI. Recognizing technical limitations in plastic manufacturing, the two LCCs achieved a respectable match with actual SR patterns of rice and maize leaves (**Figure 3CD vs 3AB**). Typical SR patterns of rice and maize leaves were similar (**Figure 3AB**) with greatest reflectance and sensitivity at 550 nm (green). Leaves with different N content would, therefore, differ greatly at this bandwidth, while differences in reflectance decrease towards both ends of the spectrum. Color panels of both charts had their greatest reflectance at 550 nm so that this condition was met. Further, the plastic panels showed equidistant reflectance among color panels at 550 nm (**Figure 3CD**), which means that the change in color was consistent from panel to panel. This confirmed the visual impression that colors of neighboring panels can be easily distinguished in both charts (**Figure 2 and 4**). The comparison shown in **Figure 3** also indicated that the new 4-panel chart may be more suitable for rice varieties in Asia compared to the LCC that was developed for rice varieties in California.

The new 4-panel LCC can be used for all modern, high yielding rice varieties in Asia, but guidelines on the use of the chart have to be adjusted to local conditions. Major progress has been made in recent years in the on-farm evaluation of LCC for effective N management and the general guidelines on its use are provided in greater detail elsewhere (Fairhurst and Witt, 2002). Briefly, a critical leaf color has to be maintained for optimal growth and the LCC provides guidance when to apply fertilizer N to avoid N deficiency. The critical leaf color depends on varietal group (inbred, hybrid, new plant type) and crop establishment method (planting density). There are two major approaches in the use of the LCC. The *fixed splitting pattern* approach provides a recommendation for the total N fertilizer requirement (kg/ha) and a plan for splitting and timing of applications in accordance with crop growth stage, cropping season, variety used, and crop establishment method. The LCC is used at critical growth stages to decide whether the recommended standard N rate would need to be adjusted up or down based on leaf color. In the *real-time* approach, a prescribed amount of fertilizer N is applied whenever the color of rice leaves falls below the critical LCC value. The critical value might fall between two existing panels of the LCC, but guidelines can be adjusted so that the color panels of the LCC will not have to be changed. Local guidelines on the LCC use have now been developed for the major irrigated rice domains in Asia.

Since its introduction in December 2003, more than 250,000 units of the 4-panel LCC have been produced and will be distributed to Asian rice farmers in Bangladesh, China, India, Indonesia, Myanmar, the



This is the actual size of the new 4-panel LCC.

Philippines, Thailand, and Vietnam. Research is underway to evaluate the suitability of the LCC for N management in maize in a joint collaborative project between the Indonesian Agency for Agricultural Research and Development and the PPI/PPIC-IPI Southeast Asia Program. BC

Note: For availability and guidelines on the use of the LCC in rice, please contact Dr. R.G. Mutters (UCCE chart) or Dr. R.J. Buresh (IRRI-UCCE chart).

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