Need Based Fertilizer Management Using Chlorophyll Meter and Leaf Colour Chart

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Abstract

Application of broad based recommended nitrogenous fertilizer often lead to under or over application due to large field to field variability with regards to nitrogen (N) availability. Over application of N often leads to environmental pollution and poor recovery of applied nitrogen. The solution to this problem is synchronizing N supply and crop demand and step up or step down fertilizer N accordingly rather than broad based application. This has been achieved by need based N management tools viz. leaf colour chart (LCC) and chlorophyll meter. Both LCC and chlorophyll meter indirectly estimate crop N status. Leaf colour chart uses reflectance of green colour from the leaf as measure of crop N status while chlorophyll meter indicates crop N status in terms of chlorophyll values which are indirect estimate of crop N status. Researchers throughout the globe have proven the credibility of need based fertilizer N management through these gadgets in agriculture settings in many crops including rice, wheat, maize etc.

Keywords: Chlorophyll meter; LCC; nitrogen; SPAD, NIR, DSR.

Introduction

In order to achieve high yields by plants farmers tend to apply nitrogen (N) higher than needed. Since nitrogen can be easily lost due to ammonia volatilization, denitrification or nitrate leaching, recovery efficiency of applied nitrogen is lowered (Bijay-Singh et al 2002). Under these circumstances, recovery efficiency of applied nitrogen can be increased by manipulating blanket recommendations to increase N use efficiency provided there is a suitable criteria present. Nitrogen status affects chlorophyll content of leaves (Schlemmer et al 2005). Since amount of chlorophyll is approximately proportional to nitrogen concentration of leaf (Evans 1983) researchers have developed an indirect way to estimate crop N status by assessing the leaf greenness which is related to photosynthetic activity and depends on leaf N content e.g. quick and nondestructive quantification of leaf greenness (indicator of N status), has been used to diagnose N deficiency indirectly rather than traditional tissue testing and to correct N fertilization and improve N use efficiency in cereal crops based on synchronized fertilizer N supply and crop demand (Bijay-Singh et al 2002).The question to determine leaf greenness was solved by chlorophyll meter viz. SPAD and leaf colour chart viz. IRRI leaf colour chart and optical sensors viz. greenseeker. These need based tools have been successfully used to estimate crop N demand based on real time or fixed time adjustable dose approach and accordingly apply fertilizer N in cereals (Bijay-Singh 2016).In this review paper need based fertilizer N management using chlorophyll meter and leaf colour chart will be discussed.

The development of the SPAD-502 chlorophyll meter by Minolta Camera Co., Ltd., Japan, has renewed interest in the use of chlorophyll content as an indicator of plant-N status. This hand-held device nondestructively estimates the chlorophyll content of leaves by measuring the difference in light attenuation at 430 and 750 nm. The 430 nm wavelength is the spectral transmittance peak for both chlorophyll a and b, whereas the 750 nm wavelength is in the near-infrared spectral region where no transmittance occurs. Increase of chlorophyll content causes a greater relative reflectance in the green as compared with in the blue and red. However, chlorophyll meter operation is based largely on the amount of absorbed red light (660 nm), which is a function of the amount of chlorophyll, and the amount of near-infrared (NIR) light (940 nm) transmitted serves as an internal reference is used to compensate for leaf thickness and moisture content (Schroder et al 2000,Scheperset al 2006). More red light absorbed by leaves means that more chlorophyll is present.

Leaf colour chart (LCC) is a high quality plastic strip on which are embedded a series of panels with colours based on the wavelength characteristics of leaves. The range of green plastic chips ranging from yellowish green to dark green cover a continuum from leaf N deficiency to excessive leaf N content (Pasuquinet al 2004). Thus, unlike chlorophyll meters that measure light absorption, LCCs measure leaf greenness and the associated leaf N by visually comparing light reflection from the surface of leaves and the LCC (Yang et al 2003). These are simple, easy-to-use, and inexpensive alternatives to chlorophyll meters (IRRI 1999) and are visual and subjective indicator of plant N deficiency. The LCCs have emerged as a highly efficient and economical substitute to chlorophyll meter for the poor and marginal farmers in countries like India (Bijay-Singh et al 2002). Developed from a Japanese prototype (Furuya 1987), several types of LCCs are available now. The most common ones are those developed by the International Rice Research Institute (IRRI) (with 4 or 6 panels); Zhejiang Agricultural University, China; and the University of California, Davis, USA with eight panels. In India, the 6-panel LCC developed by IRRI is manufactured and used for site-specific N management in rice, wheat and maize.

Need based fertilizer N management using chlorophyll meter and leaf colour chart

SPAD meter is a potent tool in indirectly determining crop N status using correlations between chlorophyll and N content. SPAD meter has widely been used to predict chlorophyll status of many crops (Jiang and Vergara 1986). Since chlorophyll content in a leaf is closely correlated with leaf N concentration (Evans 1983, Blackmer and Schepers 1994), the measurement of chlorophyll provides an indirect assessment of leaf N status. The determination of chlorophyll per unit area makes the relationship relatively independent of species (Monje and Bugbee 1992, Markwell*et al* 1995). The chlorophyll meter has the ability to detect the onset of N stress in many cases before it is visible to the human eye (Schepers*et al* 2006).

The chlorophyll meter (SPAD meter) and leaf colour chart (LCC) are basic, compact demonstrative devices used to gauge the relative chlorophyll content leaf or greenness of leaves, respectively, and thus evaluate crop N status in situ in fields to decide the planning of N top dressing (Balasubramanian*et al* 2000). To answer the inquiries of when, where and the amount, we need a checking strategy to assess the N status of yields, tissue tests and chlorophyll meters could be utilized to take choice. Inventive apparatuses, for example, chlorophyll meters are speedier than tissue testing for N and can discover when plant needs N most (Ladha*et al* 2000). Chlorophyll meter is a basic, fast furthermore, non-ruinous in situ instrument for estimating relative content of chlorophyll in leaf that is directly corresponding to leaf N content. Consequently, the SPAD meter is helpful in diagnosing the N status of plants and assurance of the opportune time of N dressings (Peng*et al* 1996). However, chlorophyll meter is excessively costly (US$1200-1800/unit) to be used by small and marginal farmers which confines its across the board use by farmers.

There are two major approaches in the use of the LCC (Witt *et al* 2005). The fixed splitting pattern approach provides a recommendation for the total N fertilizer requirement 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 colour (Bijay-Singh *et al* 2012). In the real-time approach, a prescribed amount of fertilizer N is applied whenever the colour of rice leaves falls below a critical LCC value. Local guidelines on the LCC use have now been developed for the major irrigated rice and wheat domains in India. It can be effortlessly conveyed in the pocket to field. LCC can advance need based variable rate N application to crops in view of soil N supply and harvest demand. Under functional on cultivate circumstances LCC turned out to be substitute to the chlorophyll meter strategy as far as high return and enhanced N use efficiency by facilitating need based N application is concerned (Bijay-Singh *et al* 2002). These studies suggest that much more economical LCC can be used as a viable substitute compared to the costly SPAD meter in guiding for need based N applications in crops.

The idea of utilizing spectral reflectance proportion to measure leaf greenness was accounted for in the mid sixties in Japan (Inada 1963). Later amid 80's and mid 90's the investigations (Jund and Turner 1990, Peng*et al* 1993) concentrated on utilizing devices, for example, LCC/SPAD meter in light of spectral properties of leaves in light of light transmittance through leaves for directing ongoing need based fertilizer N management in rice and wheat. These strategies have been assessed in an extensive variety of farmer's fields in Asia and are presently situated for more extensive scale approval and agriculturist adjustment. These advancements give momentary outcomes and have been shown as a successful device to plan N treatment to crops (Peng*et al* 1993). These contraptions helped proficient N management in rice (Varinderpal-Singh *et al* 2007), wheat (Shukla*et al* 2004, Maiti and Das 2006) and maize (Varinderpal-Singh *et al* 2011) under circumstances experiencing assorted variety in field, season and assortment by guaranteeing exceptional returns and giving financial advantages to the agriculturists. Bajwa*et al* (2004) watched the convenience of canopy reflectance in recognizing N deficiency in cotton fields.

Since it is cumbersome to monitor leaf greenness during entire crop growth stages on real time basis an alternative fixed-time adjustable dose involving less frequent monitoring of leaf color at more crucial growth stages in terms of crop N demand has been reported by Bijay Singh *et al* (2012) and Dobermann*et al* (2002) in rice. However, high cost of optical sensor and chlorophyll meter keeps it away from farmers. Nevertheless, researchers have shown that SPAD meter can be substituted by cheaper Leaf color chart (LCC) for managing fertilizer N in cereals using real time approach (Bijay-Singh *et al* 2002) and fixed time adjustable dose approach (Bijay-Singh *et al* 2012; Dobermann*et al* 2002). The Minolta chlorophyll meter SPAD-502 provides readings (SPAD units) which, within limits, are directly correlated with chlorophyll content and tissue N concentration (Nielsen *et al* 1995). Yang *et al* (2003) and Shukla*et al* (2004) have also reported significant coefficients of correlation between grain yield and N concentration in leaves or SPAD values recorded at critical physiological growth stages in rice and wheat. Nevertheless, the SPAD meter threshold value may vary among varieties, hybrids and environmental conditions (Varinderpal-Singh *et al* 2010). According to Sibley *et al* (1994) the values determined with SPAD-502 do not depend on or are not affected by the environmental brightness levels. The results of the application of the indirect chlorophyll meter SPAD-502 have been satisfactory for the assessment of the N nutritional status of some crops (Fox *et al* 1994).

Bullock and Anderson (1998) examined the relationship of Minolta SPAD-502 readings to applied N fertilizer rate, maize yield, and leaf N concentration. They reported that at all testing circumstances the relationship of SPAD readings to N fertilizer rate were low however noteworthy (r= 0.22 at V7 and R1, r= 0.11 at R4). SPAD relationship to comparing leaf N concentration enhanced after some time. The Pearson relationship was r= 0.33 at V7 and increased to r= 0.78 at R4. The SPAD meter, consequently, completed a great job at giving a measure of the relative greenness of living leaves at a particular point in time.

Costa *et al* (2001) examined the impact of N levels on maize hybrids by estimating chlorophyll content through SPAD meter and found that all genotypes indicated expanding SPAD perusing as plants matured until silking. By and large, SPAD meter readings increased as N treatment level increased at every estimation date. Applied N rates were fundamentally associated with the SPAD meter readings.In wheat and rice, the relationship between SPAD meter reading and N content in leaves has been found to be non-linear (Peng*et al* 1993, Shukla*et al* 2004). Peng*et al* (1993) suggested adjustment of SPAD readings for specific leaf weight to improve upon the prediction of leaf N concentration in rice. Thus, Peng*et al* (1996) and Shukla*et al* (2004) observed a linear correlation between SPAD values and rice leaf N concentration measured on leaf area basis for all the growth stages and lines tested.

Peng*et al* (1996) concentrated on deciding a fixed SPAD meter critical value that agriculturists could allude to in the field and proposed the utilization of 35 as a basic SPAD value for transplanted rice. In an examination did in South India (IRRI-CREMNET 1998), an estimation of 37 was observed to be critical for acquiring significant returns and N utilization efficiency for transplanted rice. Bijay-Singh *et al* (2002) presumed that the SPAD meter estimation of 37.5 was critical for transplanted rice in northwestern India. Maiti*et al* (2004), Nagarajan*et al* (2004) and Khurana*et al* (2007) have convincingly shown that SPAD meter based N management leads to significant increases in N use efficiency when compared with the farmers' fertilizer practices.

Rather than utilizing a flat out SPAD meter an incentive as the limit, Hussain*et al* (2000) utilized a SPAD based sufficiency index approach to decide the planning of N topdressing. The sufficiency index was computed as the level of the SPAD meter readings in the SPAD meter based plot to the SPAD readings in the well fertilized reference plot. To guarantee that no N inadequacy happened in the reference treatment, the plot got 180% to 200% of the normally prescribed N rate in the fixed planning practice. At the point when the adequacy record fell underneath 90%, 30 kg N ha^{-1} was topdressed. Rice grain yield acquired for various cultivars were similar to the blanket N application treatment yet with 30 kg less N ha^{-1}. Bijay-Singh *et al* (2006) took after sufficiency index approach for directing fertilizer N application in wet DSR. They found that following the criteria of 90% adequacy, 50 kg N ha^{-1} less fertilizer was utilized as a part of correlation with fixed time fixed dosage utilization of 120 kg N ha^{-1} with no lessening in the grain yield.Successful use of chlorophyll meters can be influenced by many factors such as variety, growth stage, leaf position and the sampling point on the leaf (Huang *et al* 2008) so the strategy should be accordingly calibrated.

The LCC technology have been established for real time N management in wheat (Varinderpal-Singh *et al* 2012), rice (Yadvinder-Singh *et al* 2007) and maize (Varinderpal-Singh *et al* 2011). Witt *et al* (2005) built up the leaf colour chart for rice and was likewise appropriate for maize as showed by spectral reflectance performed on rice and maize. In this investigation, they looked at examples of rice and maize leaves with those of the two leaf colour charts created by UCCE and IRRI. Perceiving specialized impediments in plastic assembling, the two LCCs accomplished a respectable match with examples of rice and maize which were comparable with most noteworthy reflectance and affectability at 550 nm (green).

Win (2003) reported that LCC scores were highly associated to SPAD values in rice and wheat. Similarly, Shukla*et al* (2004) compared LCC and SPAD values and reported high correlation between them with respect to rice and wheat crops. Sarnaik (2010) reported that the increased leaf greenness with the assistance of leaf colour chart based N applications affected development, yield, and N uptake in maize. Varinderpal-Singh (2011) from a long term trial during initial two years showed that LCC shade 5 at vegetative growth stage and LCC shade 5.5 at silking stage can be used for crop demand driven N applications in maize and assessment of the critical leaf greenness. In the following three years the results indicated that fertilizer N management utilizing LCC 5 beginning from six-leaf stage up to before silking stage brought about enhanced agronomic and N recovery efficiency in various maize genotypes. In sweet corn, Datturam (2011) reported that application of LCC-5 based N application was more effective with respect to yield and yield parameters compared to LCC 4 and LCC 3 based N applications. Sharp increase in efficacy of LCC to predict grain yield in late generative phase in rice has been reported by Ali *et al* (2014).

Varinderpal-Singh *et al* (2007) reported 9.4-54.2 kg N ha^{-1} less fertilizer was applied without any reduction in yield as compared to the farmers' practice of applying blanket N at fixed-time intervals in the Indian Punjab using six-panel, IRRI-LCC for managing fertilizer N in rice. The authors reported that application of fertilizer N for transplanted rice when colour of the first fully expanded leaf was less than LCC shade 4, increased N use efficiency from 48 to 65 kg grain kg N^{-1}. Yadvinder-Singh *et al* (2007) observed that application of fertilizer N for transplanted rice whenever leaf greenness was less than shade 4 on the LCC produced rice grain yield on a par with blanket recommendation Bhatia *et al* (2011) reported that the LCC-based urea application reduced nitrous oxide emission in transplanted rice. Application of 120 kg N ha^{-1} at LCC $\leq$4 decreased nitrous oxide emission by 16% and methane by 11% over the conventional split application of urea.

Witt *et al* (2007) has described the fixed-time adjustable dose strategy in which split N application doses at active tillering and panicle initiation of transplanted rice are given based on expected yield response and leaf colour defined by IRRI–LCC as yellowish green (LCC value 3), intermediate (LCC value 3.5) and green (LCC value 4). Wang *et al* (2007) have evaluated a number of variants of the fixed-time adjustable dose strategy using different critical LCC values and percentage of fertilizer N to be applied at different critical growth stages. In India, Bijay-Singh *et al* (2012) conducted a series of experiments during 2007 to 2010 with treatments refined progressively to work out appropriate combination of fixed and adjustable rates of fertilizer N at critical stages of transplanted rice. A dose of 30 kg N ha^{-1} at transplanting as prescriptive N management proved to achieve optimum yield in rice.

Varinderpal-Singh *et al* (2014) conducted 96 experiments on farm locations in Punjab to evaluate the LCC guided fertilizer N management. The leaf colour was matched with LCC only once at maximum tillering stage (second irrigation) after applying prescriptive doses of 25 kg N ha^{-1} at planting and 45 kg N ha^{-1} at crown root initiation stage for timely sown wheat. In wheat sown after mid-December, only 30 kg N ha^{-1} was applied at crown root initiation stage along with basal dose of 25 kg N ha^{-1}. The in-season plant N need at maximum tillering stage was assessed using LCC; a dose of 30 or 45 kg N ha^{-1} was applied depending on colour of the leaf to be LCC 4 or <LCC 4 in timely sown wheat. In late sown wheat 30 or 15 kg N ha^{-1} was applied depending on colour of the leaf to be LCC 4 or <LCC 4.The average site-specific use of fertilizer N was 29 kg N ha^{-1} less than the farmer's practice.

Conclusion

Blanket fertilizer recommendations often lead to lower recovery of applied nitrogen owing to lack of synchrony between crop demand and soil supply. Chlorophyll meter and leaf colour chart can be effectively used for estimating in season fertilizer N representing crop N status. Under Indian condition where majority of farmers are small and marginal leaf colour chart has been proved as viable alternative to SPAD meter for need based fertilizer N management. These tools can significantly increase recovery of applied N thereby reducing cost of cultivation and environmental hazards due to application of excess N.

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