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Real Time Nitrogen Management in Rice under Site Specific Nutrient Management

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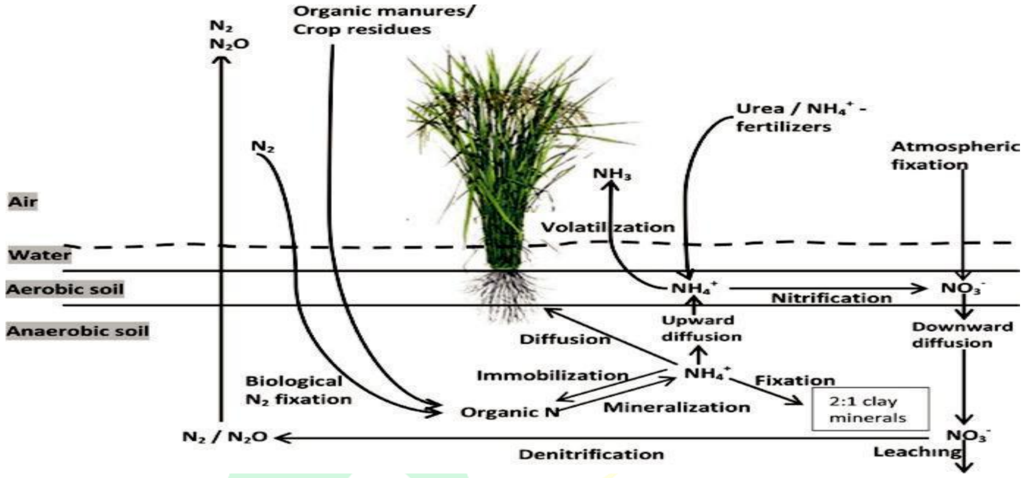
Introduction:

Rice is a staple food for more than half of the world's population. India is the world's second largest producer of rice, accounting for 20 per cent of world rice production. In India, rice is grown in an area of 45 million hectare with a production of 121.46 million tonnes and an average productivity of 2.4 t/ha. Current fertilizer N recommendations consist of fixed rates and timing for vast rice growing areas and ignore the spatial variability in soil N supply. Nitrogen is the nutrient that most often limits crop production. Crop use nitrogen inefficiently, generally more than 50% of N applied is not assimilated by plants. To enhance N-use efficiency in rice, it is necessary to know the actual amounts of N required and the right time of its application. The real time N management approach can avoid application of excessive amount of N fertilizer by matching time of fertilizer application with plant need. This approach revolves around quick and reliable diagnostic tools which are based on measurement of spectral characteristics of the radiation reflected, transmitted or absorbed by the leaves to estimate the chlorophyll content.

The blanket fertilizer recommendation consisting of three split applications of present rates of total fertilizer N during the growing season of rice is commonly used by the farmers in Punjab for managing N fertilizer. Large field-to-field variability of soil N supply, agro-climatic conditions and varietals differences restrict efficient use of fertilizer N. Thus using broad-based blanket recommendations cannot help increase N use efficiency beyond a limit. The low N use efficiency has been mainly due to its rapid mineralization and proneness to losses through different pathways before it is utilized by the crop. Due to predominantly coarse soil textures found in north-western India which result in alternating aerobic and anaerobic soil conditions under rice, applied N is readily converted to NO_3, which is prone to losses by leaching, nitrification-denitrification or both.

Various pathways of N loss in rice



Site specific nutrient management (SSNM):

According to Liebig's law of minimum, any essential plant nutrient which becomes deficient, limits plant growth and crop yields. SSNM is thus a further refinement over NPK balanced fertilization and fertilizer management is recommended on the basis of soil tests for all essential plant nutrients.

Areas of opportunity for improvement in fertilizer N use efficiency:

Continued improvement in cropping system management, use of site specific precision agricultural technologies, better prediction of soil N mineralization, improved timing of N application, improved fertilizers, improved manure management.

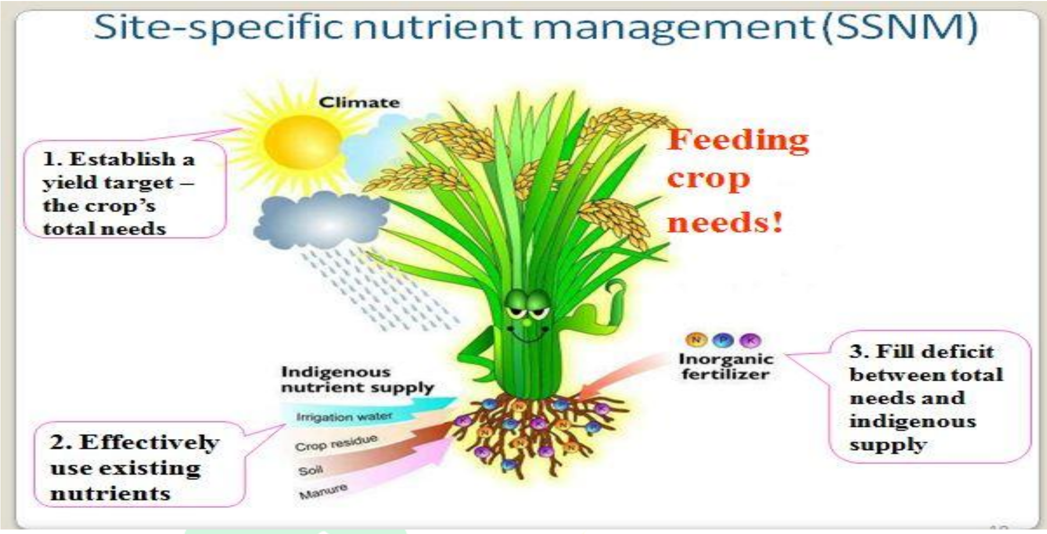
With the SSNM approach, fertilizer N recommendations for crop can be developed by:

Estimating the total fertilizer N required for crop in a typical season and then Formulating a dynamic N management to distribute fertilizer N to best match the crop's need for N.

Definition

It is an approach of fertilizer application to match field-specific needs of crops to improve productivity and profitability.

SSNM can be: (1) Prescriptive and (2) Real Time N management. Prescriptive N management relies on information generated before the planting of a crop. Real Time N management method employ diagnostic tools to assess crop N status during the growth of the crop which are used as the basis for decision about further N application.



What is Real Time Nitrogen Management?

It is a method of rapid assessment of leaf N content that is closely related to the photosynthetic rate and biomass production and is a sensitive indicator of changes in crop N demand within the growing season.

Tools for real time nitrogen management:

1. Leaf color chart:

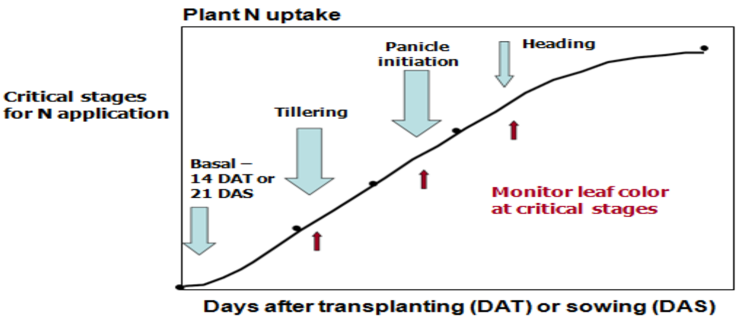
LCC is an easy-to-use and inexpensive diagnostic tool for monitoring the relative greenness of a rice leaf as an indicator of the leaf chlorophyll content and leaf nitrogen status. Japanese scientists developed an N management tool called LCC which was subsequently modified by Chinese scientists. The International Rice Research Institute (IRRI) used the concept and jointly further improved the LCC in the late 1990s to assist farmers to apply N fertilizer at right amount as and when needed by the plant. LCC is made of high quality plastic material, consisting of six green shades from light yellowish green to dark green color strips fabricated with veins resembling those of rice leaves. The colour panels of the LCC are designed to indicate whether rice plants are hungry or over-fed by nitrogen fertilizer. By matching the colour of the rice leaf to the colour on the LCC, farmers can decide proper time and amount of N fertilizer for the application.

Approaches to use of the LCC:

1. Real-time N management
2. Fixed time – adjustable dose.

A. Real time N management option

i. Apply N early
ii. Monitor leaf color at 7-10 days intervals
iii. Apply N when LCC reading is below critical value

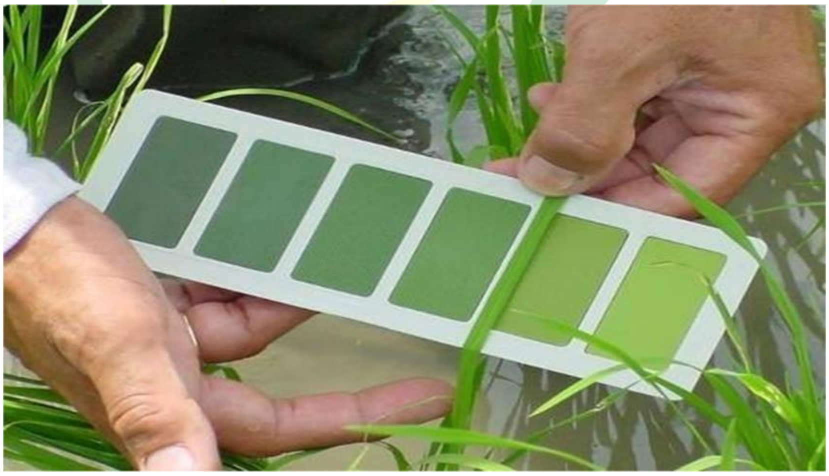


B. Fixed time/adjustable N management option

i. Apply N early
ii. Top-dress N at predetermining critical stages like basal, tillering, panicle initiation, heading by monitoring leaf color at these critical stages
iii. Adjust N dose up or down based on LCC reading.

How to measure LCC?

- An average of five disease free rice plants were randomly selected in the plot
- The color of the youngest fully expanded leaf of the selected plant was compared by placing its middle part on top of the color strip in the chart.



- The leaf colour of the index leaf (fully opened third leaf from top up to panicle emergence and boot leaf after panicle emergence) of selected plants was compared with the color strips of the chart.
- If the leaves read below required value, fertilizer N was applied.

- The colour panels of the LCC are designed to indicate whether rice plants are hungry or over-fed by nitrogen fertilizer.
- By matching the colour of the rice leaf to the colour on the LCC, farmers can decide proper time and amount of N fertilizer for the application.

Guidelines for Using the Leaf Color Chart

- Take LCC readings once every 7 to 10 days, starting from 14 days after transplanting (DAT) for transplanted rice and from 21 days after sowing to flowering for DSR.
- Choose the topmost fully expanded leaf color measurement because it reflects the N status of rice plants.
- The leaf color is measured by placing the middle part of the leaf on LCC and comparing the leaf's color with its color.
- During measurement, provide shade with your body, because leaf color reading is affected by Sun's angle and sunlight intensity. If possible, the same person should take LCC readings at the same time of the day.
- Take readings of ten leaves at randomly chosen in a plot. Alternately, if more than five leaves show reading below the set critical value, top dress N fertilizer to correct N deficiency.
- Generally, critical value for semi dwarf high yielding varieties 4.0. If the average value fall below 4.0, top dress N fertilizer (20-30 Kg ha^{-1}) to correct N deficiency.

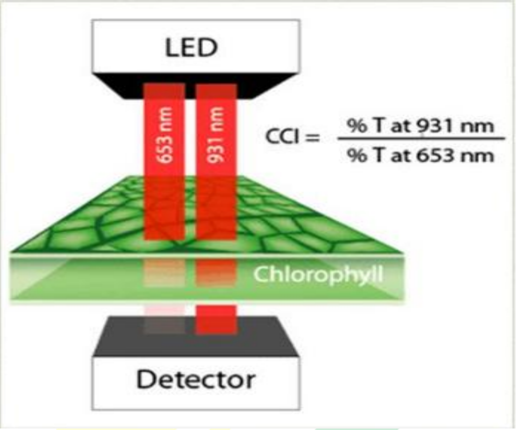
2. Soil plant and analysis development (SPAD) meter:

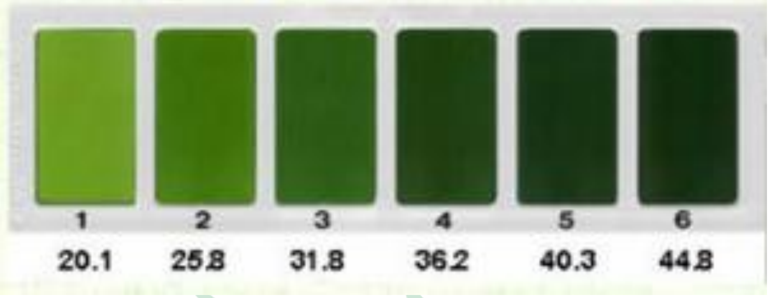
SPAD meter is a simple, quick and nondestructive in situ tool for measuring the relative content of chlorophyll in the leaf that is directly proportional to leaf N content. It instantly provides an estimate of leaf N status as chlorophyll content by clamping the unplucked leafy tissue in the meter.

SPAD reading is influenced by: 1. Nitrogen fertilizer efficiency, 2. Rice cultivar, 3. Position of leaf on plant, 4. Deficiencies of P, Zn, Mn and Fe.

Principle of SPAD:

- It uses two LEDs (light emitting diodes) which emit red light with a peak wavelength of 650 nm and an infrared radiation with a peak wavelength of 940 nm.
- The red and infrared radiations are made to pass through the leaf.
- A portion of light is absorbed and the remainder is transmitted through the leaf and a silicon photodiode detector is inversely proportional to the chlorophyll content is displayed in arbitrary units (0-99.9).





Measuring SPAD values in the field

1. SPAD readings are taken at 9-15 day intervals, starting from 14 DAT for transplanted rice and 21DAS for wet direct seeded rice, Periodic readings continue up to the first (10%) flowering.
2. The youngest fully expanded leaf of a plant is used for SPAD measurement.
3. Readings are taken on one side of the midrib of the leaf blade.
4. A mean of 10-15 readings per field or plot is taken as the measured SPAD value.

5. Whenever SPAD values fall below the critical values, N fertilizer should be applied immediately to avoid yield loss.

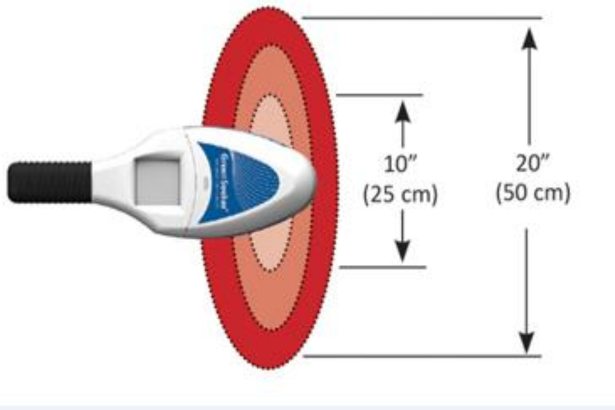
3. Greenseeker optical sensor:

Optical sensor is an important tool for replacing blanket fertilizer nitrogen recommendations in rice because it reduces the bias in making measurements and tells the quantity of fertilizer N required to achieve maximum grain yield. The Green Seeker is an instrument that provides a vegetation index of normalized difference vegetative index (NDVI), whose interpretation can contribute to the rapid and directed diagnostic nutritional conditions (especially from Nitrogen), physiological state, incidence of stress, and the potential yield of crops.

Procedure for taking NDVI values

- Before taking the readings, the battery should be charged properly.
- Then shoulder strap was put around the body and sensor angle was such adjusted that it was parallel to sensing area at a height of about 70 cm above the canopy.
- The trigger of Green Seeker optical sensor was pressed continuously while moving in the two middle crop rows and trigger was released after completing one plot.
- A photodiode detector within the sensor measured the magnitude of the light reflected off the target and NDVI was computed.

Reflection of light at leaf level is primarily dependent on the internal structure of the leaf. GreenSeeker TM hand held optical sensor (NTech industries, Inc. Ukiah. CA.) developed by Oklahoma State University, senses a 0.6 x 0.01 m area when held at a distance approximately 67 cm from the illuminated surface. The sensed dimensions remain approximately constant over the height range of sensor. The sensor unit has self-contained illumination in both red (671 + 6 nm) and near infra red (NIR) (780 + 6 nm) bands.



Principle of Green seeker:

The device measures the fraction of emitted light in the sensed area that is reflected back to the sensor (reflectance). Chlorophyll contained in the palisade layer of the leaf controls much of the visible light (400-720 nm) reflectance. Chlorophyll absorbs between 70 to 90 per cent of all incident light in the blue and red wavelength bands while reflecting light in the green band. The amount of light reflected in the visible region is defined by the chlorophyll content in the cell and the amount of light reflected in the near infra red (NIR) region is defined by living vegetation or biomass.

NDVI

Normalized difference vegetative index is a measure of total biomass and greenness of leaves and is used for mid season prediction of final grain yield. Normalized difference vegetative index (NDVI) measurements made by GreenSeeker were computed by the following equation:

NDVI = (NIR ref -RED ref)/(NIR ref + RED ref)

Where, NIR ref or Red ref represents reflectance in the near infrared and red bands.

These measurements can range from -1 to 1, being the higher values (0.7-0.8) indicators of plants in the best conditions. The highest value 1 would represent the possible high density of leaves green and healthy.

Normalized difference vegetation index (NDVI) has been widely used for indirectly obtaining the information such as photosynthetic efficiency, productivity potential and potential yield. The sensor samples at a very high rate (approximately 1000 measurements per second) and averages measurements between outputs. The sensor outputs NDVI at a rate of 10 readings per second with travel velocities at a slow walking speed of about 0.5 m s^{-1}.

Conclusion:

Use of LCC, SPAD and Green seeker as tools of Real Time Nitrogen Management were found to be superior than the existing & widely adopted blanket method of N application. These tools have tremendous potential to increase the productivity and profitability of rice besides sustaining the soil and environment health. Thus, the N management in rice will undergo radical change in the coming years which will benefit the farming community besides optimizing 'N' requirement of rice.