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SMART MANAGEMENT OF SINGLE MOST VARIABLE PRODUCTION INPUT-NITROGEN WHICH FARMERS USED IN CROP PRODUCTION

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Abstract— **Fertilizer nitrogen is the single '*Most Variable Production Input'* which farmers used in crop production. Most of the Indian soils are low in N and the requirement of N by crop is throughout its growing period, therefore, N should be applied in such a way that plant gets it throughout its life period. It becomes absolutely necessary to apply N fertilizers to every soil and crops. For this reason, the total requirement of N is more compared to fertilizers of other group. With the continued increase in fertilizer costs, nitrogen use efficiency becoming increasingly important for production as well as environmental quality. Hence, it helps in saving the N fertilizers and ultimately low cost of cultivation and less environmental impact. The major aim to reviewed this article to aware about the nitrogen, its impact over long use in environment, nitrogen use efficiency, smart management practices, new approaches of its application and whatever research to be needed regarding nitrogen would be helped to young researchers.**

Index terms- **Nitrogen, NUE, Smart N management practices, new approaches of N application, Research need to improve NUE.**

I. INTRODUCTION

During the era of Green Revolution, introduction of high-yielding varieties, extension of irrigated areas, use of high analysis NPK fertilizers and increase in cropping intensity, boosted the production in most of cases, propelled India towards self-sufficiency in food production. In the process, relative contribution of organic manures as a source of plant nutrients *vis-a-vis* chemical fertilizers declined substantially. Nitrogen (N) is a naturally occurring element in nature. However, without proper management in agricultural application it can be harmful to the surrounding environment. With increase in cost of production inputs, inorganic fertilizers became increasingly more expensive due to increase in price of fertilizers day by day. Without proper choice, injudicious use of fertilizers and high energy inputs is leading to decline in production and productivity of various crops, deterioration of soil health, impact on environment and natural eco-system.

Moreover, today the agriculture is now facing a challenge of over dependence on synthetic inputs and day by day it change in price of these inputs. The occurrence of multinutrient deficiencies and overall decline in the productive capacity of the soil due to non-judicious fertilizer use, have been widely reported. Especially, the nitrogenous fertilizers became more expensive due to increase in the price. Hence, there will more chance of N losses by many ways so that nitrogen management and saving of nitrogenous fertilizers is more important and also became a challenge.

Potential Adverse Impacts of Excessive Use of Reactive N on Ecosystem Functioning

- Loss of N retention capacity of soil because of increased mineralization
- Global warming because of increased emission of nitrous oxide, a potent greenhouse gas and Depletion of stratospheric ozone by nitrous oxide.
- Air pollution produced by nitrogen gases (nitric oxide and nitrogen dioxide), hence, Acid deposition by nitrogen oxide.
- Eutrophication because of high nitrate in aquatic ecosystems.
- Loss of biological diversity, especially losses of plants adapted to efficient use of N and Loss of soil nutrients such as calcium and potassium.
- Methemoglobinemia infants because of increased nitrate ions in water and food.

NITROGEN

Nitrogen is a chemical element that has the symbol N, atomic number of 7 and atomic mass 14. The element nitrogen was discovered by Daniel Rutherford, in 1772 and element essential for all groups of plant found by Nicolas Theodore de Saussure in 1804. Nitrogen is the first fertilizer element of the macronutrients. Nitrogen is very important nutrients for plants and it seems solar energy. The air contains about 78 per cent of Nitrogen. Plants can't use directly. But the plants belongs to family Leguminoceae, can play a host the special group of nitrogen fixing bacteria such as Rhizobium. Nitrogen is the most frequently deficient nutrient in crop production. Understanding the behavior of N in the soil is essential for maximizing agricultural productivity and profitability while reducing impact of N fertilization on the environment. The fertilizer is essential as well as expensive input in agricultural production. Fertilizer plays a leading role in increasing crop production by almost 41%. Fertilizer nitrogen is the single '***Most Variable Production Input***' which farmers used in crop production. Most of the Indian soils are low in N and the requirement of N by crop is throughout its growing period, therefore, N should be applied in such a way that plant gets it throughout its life period. It becomes absolutely necessary to apply N fertilizers to every soil and crops. For this reason, the total requirement of N is more compared to fertilizers of other group. With the continued increase in fertilizer costs, nitrogen use efficiency becoming increasingly important for production as well as environmental quality.

Role of Nitrogen

N = **N**itrogen is an essential macronutrient needed by all plants to thrive.

I = **I**nside the plant, N converts to amino acids, the building blocks for proteins.

T = **T**ransfer energy compounds, such as ATP.

R = **R**egulate the utilization of P and K and other constituent.

O = **O**verall growth, development, reproduction, quality of produce depend on nitrogen.

G = **G**row plant more rapidly and produce large amounts of succulent.

E = **E**ncourage vegetative growth and imparts dark green colour to plants.

N = **N**itrogen serves as the source for the dark green color in the leaves of various crops.

Forms of soil nitrogen: The total N content of soil ranges from 0.02% in sub-soil to more than 2.5% in peats. The N present in soil can classified as organic and inorganic form. 1) **Organic nitrogen compounds:** The organic forms of soil nitrogen occur as consolidated amino acids or protein, free amino acid, amino sugars and other complex compounds. 2) **Inorganic nitrogen compounds:** It includes ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), nitrous oxides (N_2O), nitric oxides (NO) and elemental nitrogen (N). The source of N used by plants is N_2 gas, which constitutes 78 % of the earth's atmosphere. Unfortunately, higher plant cannot metabolize N_2 directly into protein. Nitrogen gas must be converted to a plant available form by one of the following methods. 1) Fixation by microorganisms that live symbiotically on the roots of legumes and certain non leguminous crops. 2) Fixation by free living or non symbiotic soil microorganisms. 3) Fixation as oxides of N by atmospheric electrical discharges and 4) Fixation as NH_3, NO_3, or CN_2 by the manufacture of synthetic N fertilizers.

Factors affecting total N content in soils: Climate, Texture, Agricultural practices includes Cultivation, Tillage, Organic manures and fertilizers and Crop residues.

Sources of N for Plant Growth:

Nitrogen can be supplied for plant growth from several sources: The atmosphere by biological fixation, atmospheric fixation, precipitation and soil organic matter, crop residues and animal manures and by Commercial fertilizers **1. Nitrate fertilizers:** Sodium nitrate, Calcium nitrate **2. Ammonium fertilizers:** Ammonium sulphate, Ammonium phosphate, Ammonium chloride, Anhydrous ammonia, Ammonia solution **3. Nitrate and Ammoniacal fertilizers:** Ammonium nitrate, Calcium Ammonium Nitrate (CAN), Ammonium Sulphate Nitrate **4. Amide fertilizers:** Urea, Calcium cynamide.

Nitrogen behavior in environment: Managing nitrogen inputs to achieve a balance between profitable crop production and minimizing nitrogen loss to the environment should be every producer's goal. The behavior of nitrogen in the soil system is complex, yet understanding the basic processes can lead to a more efficient nitrogen management program.

Nitrogen Cycle: Nitrogen is important to all life. Nitrogen is changing its chemical form continually and moving from plants through animals, soil, water and the atmosphere. This movement and transformation of nitrogen in the environment is known as the "**Nitrogen Cycle**''. Critical processes in the nitrogen cycle affecting manure handling and plant growth include the following: Mineralization, Nitrification, Immobilization, Volatilization, Denitrification and Leaching

Nitrogen Transformations: Nitrogen, present or added to the soil, is subject to several changes called transformations that dictate the availability of N to plants and influence the potential movement of NO_3^- to water supplies. i.e. Mineralization, Nitrification, Denitrification and Immobilization

Nitrogen Loss from the Soil System: Nitrogen is lost from the soil system in several ways: Leaching, Denitrification, Volatilization, Crop removal, Remove by weeds and Soil erosion and runoff.

Nitrogen interaction with soil

Soil consists of many negatively charged mineral and organic particles. A measure of the total negative charge in soil is called its CEC. Most soils have enough exchange capacity to adsorb and hold all positively charged particles or nutrients in soils. While the soils exchange capacity can hold ammonium ions, nitrate is a negatively charged nutrient and the negatively charged soil particles generally repel it, causing it to remain in the soil solution. Water moving through soil will leave most nutrients "stuck" on the soil cation exchange sites. Nitrate is extremely soluble in water, so water picks it up and carries it along while moving through the soil.

Nitrogen Timing

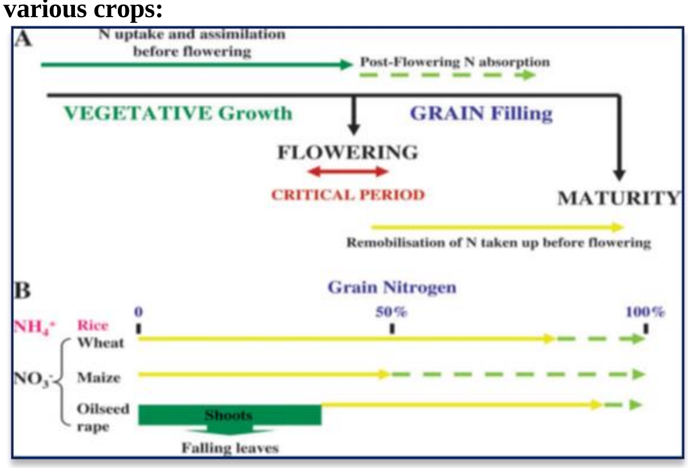
Timing of nitrogen fertilizer applications is complex. There are substantial risks associated with applications that are too early or too late depend on the weather. Ideally, nitrogen fertilizer would be applied just before the crop's peak demand for N. For corn, this would be knee to thigh high, for wheat it would be just before jointing, and for cotton it would be at early square stage.

Firstly, N requirement of growing plant is less in early stage of growth, maximum during its grand growth period and very low at the subsequent stages up to harvest. It is thus seen that N is required throughout the growth period. Secondly, if N fertilizers give out the entire amount of added N in available form in very short period, the crop is unable to use entire available amount in such a short period. Thirdly, the N not used by a crop is either lost due to leaching and volatilization due to high mobility in soil and movement in all direction, or fixed as NH_4^+ by clay particle and immobilized by microorganisms.

In general, the crop recovery of N is seldom exceeds 60 to 70 % of that added as fertilizer. Under these circumstances, one should be careful for the use of N fertilizers. Therefore, the N fertilizers should be used or manufactured to act in soil such a way that there should be minimum loss, maximum recovery and availability should be throughout the growth period as per requirement of the crop. Application of nitrogen fertilizer shall be timed to coincide as closely as possible to the periods of maximum crop plant uptake. Factors such as plant age, soil nitrogen supplies, pest infestations, climatic variations, and soil moisture status can the rate of daily nitrogen uptake, expressed in pounds of nitrogen taken up per acre per day. Nitrogen flux is another term for daily nitrogen uptake.

A generalized pattern of daily nitrogen uptake rates observed in annual plants. Periods of lowest nitrogen uptake occur during the seedling and pre-harvest periods. Early in the season plants are small and nitrogen demand is low. During the maturation period prior to harvest, crop root systems are declining in their ability to take up nutrients and water and intra-plant nitrogen demands are often satisfied. The period of highest nitrogen demand typically occurs during the middle of the season when vegetative structures are growing rapidly and fruiting structures are also developing. Crops which are harvested during the vegetative portion of their growth cycle can exhibit high rates of nitrogen uptake right up until harvest. Examples of these crops include lettuce, broccoli, cauliflower and other non fruiting vegetables.

Schematic representation of nitrogen management in various crops:



(A) During vegetative growth, N is taken up by the roots and assimilated to build up plant cellular structures. After flowering, the N accumulated in the vegetative parts of the plant is remobilized and translocated to the grain. In most crop species a substantial amount of N is absorbed after flowering to contribute to grain protein deposition. (B) The relative contribution (%) of N remobilization and post-flowering N uptake in different crops. In case of oilseed rape, a large amount of the N taken up during the vegetative growth phase is lost due to the falling of the leaves.

Nitrogen Management

Nitrogen management is one in which the time and amount of nitrogen application is prescribed prior to planting, accounting for soil nitrogen supply, crop nitrogen demand, fertilizer nitrogen efficiency and fertilizer and crop prices.

Smart N management comprise

- Precision nitrogen management
- Real time nitrogen management
- Site specific nitrogen management
- Need based nitrogen application
- Split or slow release N management

Smart nitrogen management means…

Farmers generally apply nitrogen fertilizer in several splits, but the number of splits, amount of nitrogen applied per split, and the time of applications are not as per requirement as well as not as per recommended. When N loss is minimized, the nitrogen available to growing plants is maximized. Smart use of nitrogen is an excellent way to ensure viable and productive resources for years to come.

The 4 R's principles of nutrient management

Right Source – Ensure a balanced supply of essential nutrients, considering both naturally available sources and the characteristics of specific products, in plant available forms, **Right Rate –** Assess and make decisions based on soil nutrient supply and plant demand, **Right Time –** Assess and make decisions based on the dynamics of crop uptake, soil supply, nutrient loss risks, and field operation logistics and **Right Place –** Address root-soil dynamics and nutrient movement, and manage spatial variability within the field to meet site-specific crop needs and limit potential losses from the field.

Nitrogen Management Practices.

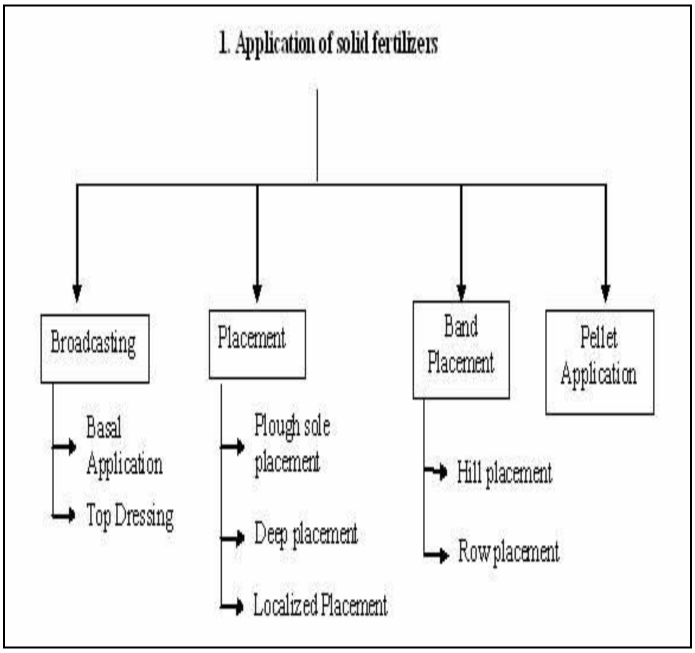
- Selection of Nitrogen fertilizers
- Rate of application
- Method of application
- Split application
- Real Time N management or Site Specific Nitrogen Management or Precision N management
- Use of slow-release N fertilizers (SRF)
  - ✓ Nitrification inhibitors (NI's)
  - ✓ Urease inhibitors
- Balanced fertilization
- Site Specific Nutrient Management (SSNM)
- Integrated nitrogen management
- New approaches *viz.* GPS, GIS & VRA (Variable Rate Application)

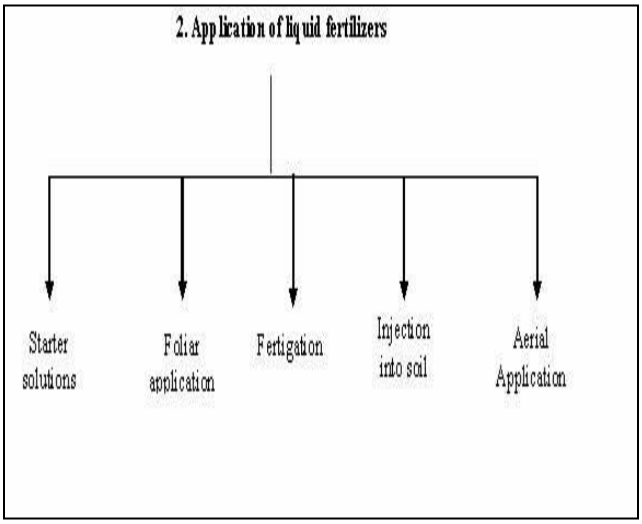
Nitrogen fertilizers: Globally the percentage share of N by different sources is: urea 51%, ammonium nitrate 7%, anhydrous ammonia 4% (mostly USA), nitrogen solutions 5%, ammonium phosphate 6% and others 27%. In India urea contributes 81% of fertilizer N used in the country, while ammonium sulphate, calcium nitrate and ammonium chloride contribute only 1%; the rest 18% is contributed by DAP and other NP/NPK materials (FAI, 2006).

Rate of application: According to the law of diminishing returns, in general, agronomic efficiency (AEn: Kg increase in grain yield over control per kg N) and recovery efficiency N (REn: % N recovered in above ground plant parts) of applied N decline as the rate of application is increased. Bindhani *et al*. (2007) concluded that baby corn should be fertilized with 120 kg N/ha in 3 equal splits at basal, 25 & 40 DAS to obtain higher marketable yield and net return. N content in baby corn and green fodder, total uptake of N protein content and apparent n recovery is found higher with 120 kg N/ha in 3 equal splits.

Method of application: Nitrogen is mostly broadcast applied in India and other Asian countries and only in recent years its placement has received attention. In Punjab and other states of India where mechanized agriculture is practiced used seed-cum-fertilizer drills. Humphreys *et al.* (1992) reported that recovery efficiency of N was 37% for broadcast, 46% for banding and 49% for deep point placement in direct-seeded rice in Australia.

Methods of fertilizer application





Split application

Split application is a well proven and well accepted method of increasing nitrogen use efficiency (NUE) in most irrigated crops (Prasad, 2007).

- Consider Split Application Crop by Crop
- Use Research-Based Recommendations
- Source and Placement for Better Yields and Less N Loss

Nitrogen Use Efficiency (NUE)

Nitrogen Use Efficiency (NUE) is a term used to indicate the ratio between the amount of fertilizer N removed from the field by the crop and the amount of fertilizer N applied. Can be calculated as the ratio and expressed in %.

Methods to measure or calculate NUE

1. Use of labeled N to trace the fate of applied N Precise, but expensive method
2. Difference method

(N crop uptake fertilized – N crop uptake unfertilized) / N fertilizer input

3. Output-input ratio: Crop N removal/mineral N fertilizer input

The main reasons for these low values for N use efficiency (NUE) are different in developing and developed countries. While in developing countries the major problem is that most N is broadcast applied leading to increased ammonia volatilization and other losses. The problem in developed nations is fertilizing for maximum economic returns or even more than that.

Reasons of Declining N Use Efficiency

1. Soil N reserve declining
2. Soil N supply pattern changing
3. Misuse (or excess) of N

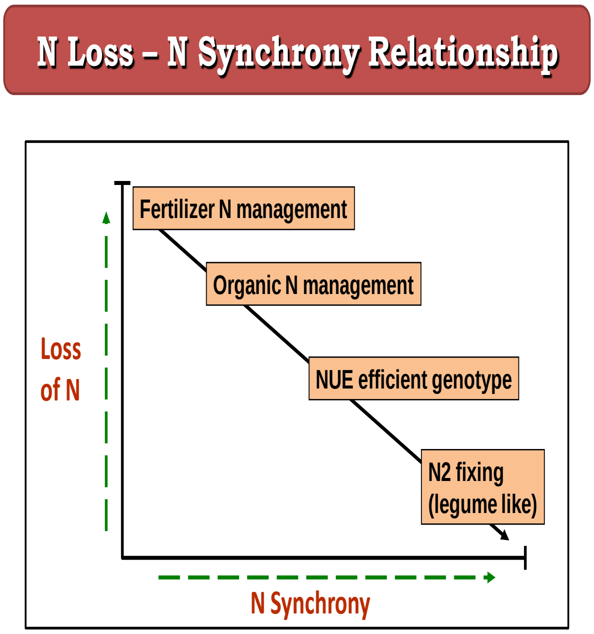
Strategies to Improve NUE

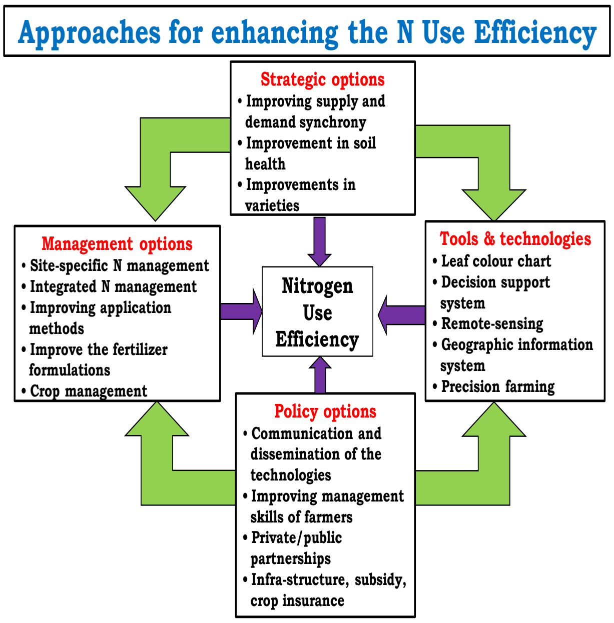
1. Resource Management

- Fertilizer N
    - Plant-need based application
    - Slow release formulations
- Organic N
    - Manipulation of residues

2. Genetic Manipulation

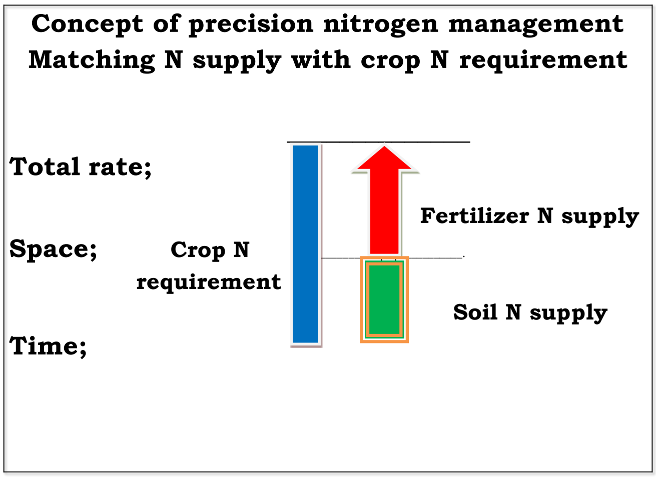
- Genotype Improvement
  - Acquisition
  - Usage pattern
  - N_2 fix-symbiosis

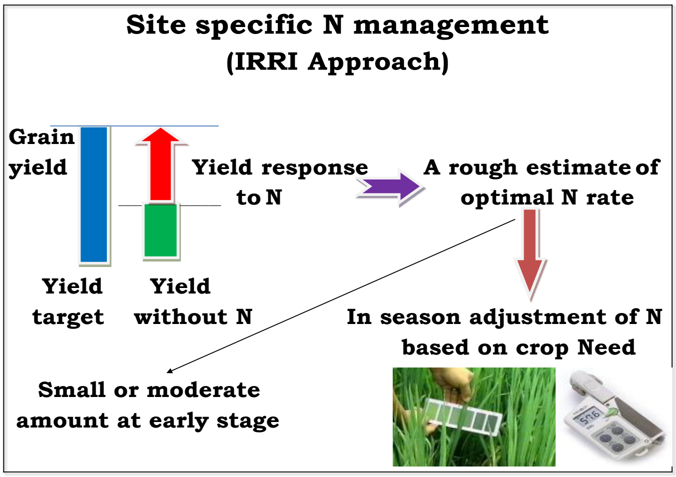




Real Time N management or Site Specific N Management

The basic objective in SSNM / Precision N management is to optimize the congruence of supply and demand of N. In SSNM, prescriptive N management relies on earlier information on the availability of native soil N, crop N need and its duration, while corrective N management is based on diagnostic tools such as chlorophyll meter (SPAD) and leaf colour chart (LCC). Of the two diagnostic tools; LCC is inexpensive and can be used by the farmers in developing countries (IRRI-CREMNET 2001).





Methods to improve timing and rate of N fertilizer in balance with N demand and N supply

1. In- season soil testing for available N and/or plant tissue tests for N status- Relatively expensive and require access to public or commercial lab service.

2. Crop and soil simulation models- None rigorously validated across soil types, environments, cropping systems, years.

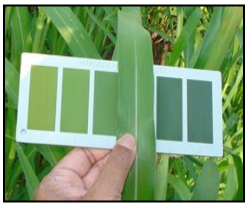
3. Non-destructive measurement of crop N status- Chlorophyll meter, leaf color chat (LCC), remote sensing**.**

Real Time N Management

Also called crop need based N management in which timing and rate of N application depend on crop N demand. Developed based on leaf photosynthesis, tillering, and leaf area growth. Aim to achieve optimum leaf N status throughout growing season. Leaf N content is a sensitive indicator of dynamic changes in crop N demand. The key is to establish the method for rapid diagnosis of leaf N status.

The value of soil test prior to planting to evaluate fertilizer requirement is not well understood. The soil testing or leaf analysis is expensive and time consuming. In addition, tissue testing is a destructive method. One of the emerging technologies is the determination of the plant for N status in combination with soil testing. At the beginning of the season, a fixed N recommendation is given, but crop development and related N needs are strongly influenced by unexpected factors during the growing season.

Leaf colour chart (LCC) is the promising tool developed in recent years for need based N management in cereal crop**.** LCC and SPAD method of N application are equally efficient in precision N management. A calibrated LCC is used to estimate crop N demand through the growing season, and applications are made at predetermined critical growth stages. Singh *et al.* (2010) concluded that LCC based N management by using saved 20 kg N/ha and found critical for N application than blanket application.



SPAD Meter
LCC

Leaf Color Chart (LCC)

The LCC is an innovative cost effective tool for real time or need-based N management in rice, wheat and maize. LCC is a visual and subjective indicator of plant nitrogen deficiency and is an inexpensive, easy to use and alternative to chlorophyll meter /SPAD meter. It measures leaf color intensity that is related to leaf N status. LCC is an ideal tool to optimize N use at high yield levels, irrespective of the source of N applied. Thus, it is an eco-friendly tool in the hands of farmers. Now, it is manufactured with 4 colors called Four Panel & 6 colors called Six Panel LCC. Moreover, LCC is provided with water-proof laminated instruction sticker in the required regional language. Singh *et al*. (2011) revealed that in maize, fertilizer N can be more effectively managed by applying fertilize N based on shade 5 with saving of 25-50 % fertilizer than blanket application. The grain yield, recovery efficiency and agronomic efficiency also found higher in case of LCC based fertilization. LCC being cost effective, simple and farmer's gadget can be easily used by small and illiterate farmers.

How to use the LCC?

Randomly select at least 10 disease-free plants or hills in a field with uniform plant population. Select the topmost fully expanded leaf from each hill or plant. Place the middle part of the leaf on a chart and compare the leaf color with the color panels of the LCC. Do not detach or destroy the leaf. Measure the leaf color under the shade of your body (direct sunlight affects leaf color readings). Determine the average LCC reading for the selected leaves.

Real time N management option

- Apply N early
- Monitor leaf colour at 7-10 days intervals
- Apply N when LCC reading is below critical value

Fixed time/adjustable N management option

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

Potential savings in urea by using the LCC method

Country	Irrigated rice area, '000 ha#	Mean number of crops per year	Saving in urea per year*, '000 t			
			25 % farmers use LCC	50 % farmers use LCC	75 % farmers use LCC	100 % farmers use LCC
Bangladesh	3,488	2	87.2	261.6	261.6	348.8
India	**22,250**	**1.5**	**417.2**	**834.4**	**1,251.6**	**1,668.8**
Indonesia	6,318	2	158.0	316.0	474	632.0
Philippines	2,248	2	56.2	112.4	168.6	224.8
Thailand	1,960	2	49.0	98.0	147.0	196.0
Vietnam	3,978	2	99.5	199.0	297.7	398.0
Asia (China)	--	--	**999.7**	**1,999.4**	**2,999.1**	**3,998.8**

Source: www.nitrogenparameters.com

Purpose of Using LCC

Purpose of using LCC is to apply adequate amount of nitrogen and avoid application of fertilizer more than required. Use of LCC helps to determine nitrogen demand of the crop and guide right time of fertilizer nitrogen application so as to prevent unwanted nitrogen losses and their serious impacts on the ecosystem.

Advantages of using LCC

- ✓ More Crop
- ✓ Less Cost
- ✓ Avoid Disease
- ✓ Reduction of GHG Emission

Chlorophyll meter or SPAD meter

The use of chlorophyll meter is based on the fact that leaf greenness is determined by N concentration which in turn is correlated with yield. It displays 3- digit SPAD value proportional to the amount of chlorophyll present in the leaf by measuring the transmittance of leaf in two wavelengths (600-700 nm and 400-500 nm). Singh *et al.* (1999) revealed that chlorophyll meter based N-management saved 20 kg N/ha in rice. A SPAD value of 37.5 and LCC reading <5 were found critical for N application in rice. Singh *et al.* (2010) suggested that SPAD value 37.5 is critical for rice and appropriate for guiding need based and top dressing of N fertilizer. Bijay singh *et al.* (2006) concluded that need based N management by using SPAD value in rice saved 50 kg N/ha than blanket recommendation and also recovery efficiency and agronomic efficiency found more in case of SPAD based fertilization. Duttarganvi *et al.* (2011) find that N application at SPAD value of 37.5 was achieved highest net return in rice crop. Thus study indicates that LCC and SPAD meter could optimum and comparable with recommended and farmer's method of application. Maiti *et al*. (2004) suggested that the mean LCC and SPAD values were positively and significantly correlated at all growth stages with mean grain yield of rice. SPAD showed higher correlation over LCC to achieve the greater yield and increased NUE significantly through SPAD over LCC. But the LCC can also used for top dressing as it is low cost and easy to handle in field as compared to SPAD, which is expensive and require technical skill for its operation.

Advantages of SPAD meter:

- ✓ Compact and light weight for portability
- ✓ Quick, easy measurement
- ✓ Water-resistant
- ✓ Low power consumption
- ✓ Small measuring area
- ✓ High accuracy
- ✓ Data memory
- ✓ Reading checker

Limitations in the use of need based N management technology

Many factors determine leaf greenness. Water stress or deficiency of nutrients other than N is supposed to affect green colour intensity and thus SPAD/LCC readings. Plant infested with diseases or insects should not be selected for measurements with SPAD meter or matching colour with LCC. Real-time need based fertilizer N requires frequent observations involving additional labour.

Research needs

Threshold LCC and SPAD values need to be worked out more rationally for different varietal groups and for different types of rice, wheat and different crops. LCC and SPAD meter can guide in season need based N management even under unfavorable agro-climatic conditions. There is a need to define the stress conditions when need based N management will not work. Fertilizer N management using LCC or SPAD meter methodology needs to be perfected. More research is needed to define threshold LCC/SPAD values to guide fertilizer N applications at different growth stages of the crops.

Green seaker- Hand held optical sensor: Optically estimates plant biomass, total N in the crop and plant stress. Data can be used to calculate response index for added fertilizer. **N-TESTER:** N Tester is a hand held tool which enables quick and easy measurements to be taken through a growing crop to establish its exact Nitrogen requirement. This can result in more accurate field scale Nitrogen recommendations, improving profitability and minimizing environmental effect. **N-SENSOR:** The YARA N-Sensor® is an ideal tool for intelligent, variable-rate nitrogen fertilization. There are about 900 YARA N-Sensors in use throughout the world, and of these more than 470 systems are in use in Germany. Currently between 300,000 and 500,000 ha of arable land are being fertilised with the help of the YARA N-Sensor in Germany.

Use of slow-release N fertilizers

The slow-release N-fertilizers release N slowly and it can be taken up by crop plants before it is lost. Most SRF materials give higher yields compared to conventional fertilizers, but their high costs have limited their use in crop production on a large scale. i.e. Environmentally Smart Nitrogen (ESN)- Coated Urea. Slow-release N fertilizers (SRF) are of two kinds, namely, coated fertilizers [sulphur coated urea (SCU), polymer coated urea (PCU), gypsum/rock phosphate coated urea, lac coated urea etc.] and inherently slow release materials [ureaform, urea Z, Isobutylidene diurea (IBDU) etc.].

Understanding the value of slow release nitrogen fertilizers

Why consider slow-release?

- ✓ There is a fundamental flaw in how we apply N fertilizer – we don't apply N as the crop needs it. In some cases, applying all N at pre-plant does not result in optimal use of N.
- ✓ N is subject to environmental losses.
- ✓ Consider slow N when attempting to reduce environmental losses
- ✓ Slow-release fertilizer is becoming more cost effective

Fertilizer Technologies

❖ **Three general categories:**

Uncoated, slow-release N- Urea-formaldehyde reaction products, Isobutylidene diurea (IBDU), Inorganic salts - Magnesium ammonium phosphate

Coated, slow-release N

Sulfur-coated urea - Releases N through oxidation of S coating, Used for turf fertilization, **Polymer-coated (or Poly-coated) urea-** Urea is coated with special polymer coating – special to each manufacturer. Water moves in through coating to dissolve urea. N diffuses out through porous polymer membrane. Popular for conventional agriculture systems, **ESN (Environmentally Smart Nitrogen, Agrium, Polyon** ® (Agrium, Calgary, AB) and **Bio-inhibitors-** Nitrification inhibitors, Urease inhibitors

What is ESN?

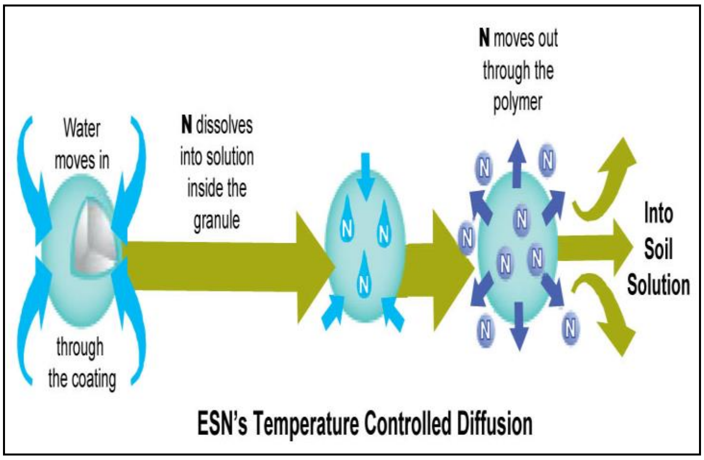
ESN is a controlled release nitrogen (N) fertilizer. It consists of a quality urea granule contained within a proprietary polyurethane coating. The N fertilizer is encapsulated and isolated from its surrounding environment which makes it unique from conventional N fertilizers. The analysis of ESN is 44-0-0.

How does ESN work?

The unique polymer coating allows water to diffuse into the granule, dissolving the N within. The N liquefies into a solution yet remains encapsulated within the coating. Nitrogen release from the granule is driven by two factors; temperature and moisture. The release rate of N remains relatively stable with increasing amounts of water. The higher the temperature, the greater release of N.

How ESN technology protects against N loss?

- ✓ Coated nitrogen granules
- ✓ Temperature controlled release



Bio-inhibitors

Nitrification inhibitors (NI's)

Nitrification inhibitors are a group of a chemical that are toxic to *Nitrosomonas* sp. and *Nitrosococcus* sp. involved in the conversion of NH4+ to N02 and which leads to reduction in losses due to leaching and denitrification. The most widely used NTs are N-Serve (2-chloro-6-trichloromethyl pyridine), AM (2 amino-4-chloro-6-methyl pyrimidine), DCD (dicyandiamide) and ST (sulphathiazole).

Urease inhibitors

The first transformation that urea undergoes when applied to a moist soil is its hydrolysis by the enzyme urease to ammonium carbonate and ammonium thus formed is subject to ammonia volatilization loss. N-(n-butyl) triophosphoric triamide (NBPT) Agrotain ®

Balanced fertilization

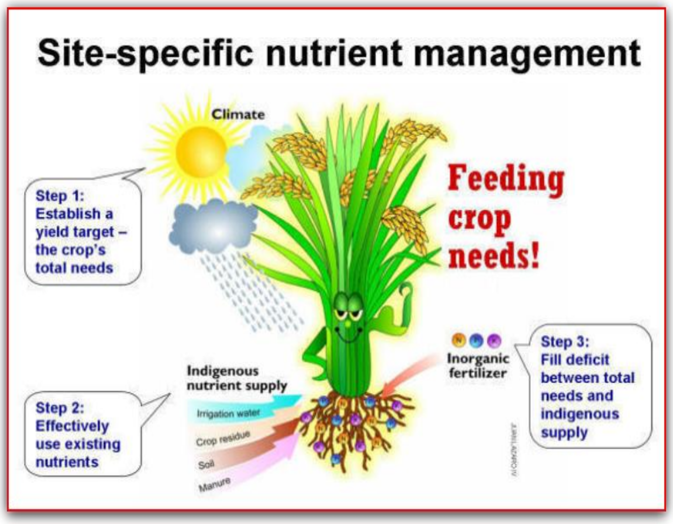
Balanced fertilization generally refers to the application of three major plant nutrients in adequate and balanced amounts as in relation to crop needs. The ideal ratio of N:P:K is 4:2:1.

Site Specific Nutrient Management

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.

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.



Integrated nitrogen management

Integrated nitrogen management refers to combined use of fertilizer N and organic N, which includes N fixed by legumes and other organisms *(Azotobacter, Azospirilium,* blue green algae, Azolla etc.) and N supplied by organic manures such as farmyard manure, compost, Vermicompost, legume crop residues, animal refuse etc.

New approaches

1. Transfer of Nif (Nitrogen fixation) genes to cereals,
2. Developing physiologically higher N efficient genotypes,
3. Development of simulation models for more efficient N prescriptions.
4. Remote sensing tools (GPS, GIS & VRA).

II. CONCLUSION

By the in-judicious use of chemical fertilizers, farmers are happy of getting maximum yield in agriculture in the beginning. But slowly, the chemical fertilizers especially nitrogenous fertilizers started showing their ill-effect such as leaching out, volatilization and lower NUE. Hence, fertilizer prices increasing day by day this leads more cost of cultivation and impact on environment. As fertilizer N has generally been managed blanket recommendations consisting of two or three split applications of the total amount of N, improvement in NUE could not be achieved beyond a limit. Approaches such as deep placement of urea super granules, controlled release have been successful in improving fertilizer NUE but to a limited extent. Feeding crop N needs is the most appropriate fertilizer N management strategy to further improve NUE. Since plant growth reflects the total N supply from all sources, plant N status at any given time should be a better indicator of the N availability. The SPAD meter and LCC have emerged as diagnostic tools which can indirectly estimate crop N status of the growing crops and help define time and quantity of in-season fertilizer N top dressings. It can be achieved by real-time N management based on periodic assessment of plant N status and delaying application of fertilizer N until N level goes below a fixed or a dynamic critical level. Supplemental fertilizer N applications are thus synchronized with the N needs of crop. Hence, it helps in saving the N fertilizers and ultimately low cost of cultivation and less environmental impact.

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