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Review Article

PRECISION NITROGEN MANAGEMENT IN CEREAL CROPS

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Abstract: India is the third largest producer and second largest consumer of Chemical fertilizer in the world, after China. The total production of nitrogen (N) in India was 13.43 million tons during 2017-18. However, the consumption of N was 16.96 million tons during 2017-18. So 3.43 million tones N was imported by India during 2017-18. Cereals are the maximum consumer of nitrogenous fertilizer. Cereals are the major source of food and fodder. Total cereal production of India is 251 Million tons during 2017-18. It is main source of energy for human being and animals. It play vital role for synthesis of chlorophyll and protein. Nitrogen use efficiency is very less (25-30%), because it is lost very easily through volatilization and leaching so precision nitrogen management is required. Low use efficiency of nitrogen fertilizers in agriculture contributes to different environmental impact like eutrophication of surface water bodies, acidification of agricultural soil and increased concentration of nitrous oxides in atmosphere contributing to global warming. Split application of the N fertilizer to cereal may reduce the rapid nitrous oxide emission and increase nitrogen use efficiency (NUE). Leaf Color Chart (LCC), Soil Plant Analysis Development (SPAD) meter, site specific nutrient management (SSNM), crop canopy sensor, crop stimulation models and controlled release fertilizers (CRF) are effective tools of precision N management. Around 10-25 % nitrogen can save through precision nitrogen management. According to our discussion LCC an ideal tool and eco-friendly to optimize NUE irrespective to N applied.

Keywords: *Cereal, Fertilizer, Leaf color chart, Nitrogen Significant*

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Introduction

Agriculture glory of India must be support all the way through attain self-sufficiency in food production first; secondly by improving our agriculture image at global arena, through strong presence in global agriculture market. No doubt, Cereals and coarse cereals should be a front leader in this endeavourer because they are the major source of food and fodder. India is the second largest and first producer of rice, wheat and millets, the world's most important energy driving staples food [1,2].Total cereal production of India is 251 Million tons during 2017-18 [3]. All cereal grains contain high energy values, mainly from the starch fraction, but, some amount also from the invisible fat and protein portions. Nitrogen being a major nutrient for production of cereals. It is vital element for proper growth and development of plants which significantly augment and enhances the yield and its quality by playing an essential role in biochemical and physiological functions of plant. Nitrogen use efficiency is very less (25-30%) [4] because it is lost very easily through volatilization and leaching so precision nitrogen management is required. The development of N management strategies that use innovative techniques, such as remote sensing, global positioning systems, and variable-rate application to account for within field variation might help to increase the efficiency of N use, reduce environmental impact and improve overall product quality at the farm level.

Materials and Methods

This paper is based on a desk review of available literature. Studies related to precision nitrogen management. This paper present the:

Important of N Fertilizer and N-Losses

There is no way of leaving N from crop production scenario of the country where without N fertilization grain production would have been 80 million tonnes which now stands at 234.47 MT with N fertilizer. However, barring di-nitrogen (N_2), which cannot be directly used in agriculture, all reactive forms of nitrogen (urea, ammonia, nitrate and their derivatives) used to produce food can threaten the environment. N based fertilizers constitute a major fertilizers constitute a major fraction, nearly 60 percent, of the total fertilizer material. Worldwide, Nitrogen Use Efficiency for cereal production (wheat, rice, maize, barley, sorghum, millet, oat and rye) is low as 33%. The unaccounted 67% represents an annual loss of N fertilizer worth up to Rs. 72000 cr. The major factor responsible for the low response of crops to fertilizer nitrogen is its low use efficiency, particularly in case of rice crop where it is only 30–40% of applied N due to various N loss mechanisms, namely, surface run-off, ammonia volatilization, leaching and de-nitrification. In 1995, the global estimate of nitrogen loss, from the applied fertilizer N through ammonia volatilization was 11.2 Mt (14.45%), while that through NO and N_2O through de-nitrification was 1.5 Mt (1%). India's contribution to these losses could approximately be 10% of the total. Ammonia added to the atmosphere leads to the acid rain, while NO and N_2O are responsible for the depletion of ozone layer in the atmosphere. In addition, nitrates leach to the groundwater and lead to the nitrate pollution of drinking water which is injurious to health [5]. Loss of N from soil plant system results from gaseous plant emission, de-nitrification, surface runoff, volatilization and leaching beyond rooting zones of crops.

Effect of excess application of nitrogen

Plants receiving excessive nitrogen have leaves become dark green color and excess negative growth occurs. As a result, the stems are not able to hold plants upright and they lodge or fall over with the slightest of wind, resulting in reduced yield, quality and harvest ability. Crop maturity is delayed and the plants are more susceptible to disease and insect pest [6].

Why precision nitrogen management required?

India is the third largest producer and second largest consumer of Chemical fertilizers in the world, after China. The total production of N in India was 13.43 million tons during 2017-18. However, the consumption of N was 16.96 million tons during 2017-18.So3.53 million tonnes N was imported by India during 2017-18. The partial decontrol of fertilizer sector (2010) which has led to sharp increase in prices of phosphate and potassic fertilizers and relatively cheaper nitrogenous fertilizers resulted in sharp fall in demand and consumption of phosphate and potassic fertilizers. The sale of urea increased by 4.4 percent during 2011-12 compared with 2010-11 while sale of DAP declined by 2.9 percent and M_OP by nearly 23 percent. This has led to deterioration in the N:P:K ratio, which will adversely affect the productivity of soil.

What is Precision Nitrogen Management?

Precision nitrogen management -the 4 R's

• Applying the right rate
• At right time
• In the right place
• Using the right source and balance

Following tools are used for precision nitrogen management in cereals

• Leaf color chart
• Site specific nutrient management
• Chlorophyll meter (SPAD meter)
• Crop canopy sensor
• Crop simulation model
• Controlled release nitrogen fertilizer

1) Leaf color chart for nitrogen management:

Leaf color charts (LCC) offer substantial opportunities for farmers to estimate plant nitrogen (N) demand in real time for their efficient use. Indian farmers generally apply fertilizer N in a series of split applications, but the number of splits, amount of N applied per split and the time of applications vary substantially.

How to use the LCC?

• Select at least 10 disease-free plants
• Select the topmost fully expanded leaf and compare the leaf colour with the colour panels of the LCC and do not detach or destroy the leaf
• Measure the leaf color under the shade of your body
• Determine the average LCC reading for the selected leaves
• If more than five out of ten leaves read below a set critical value apply nitrogen fertilizers immediately to avoid yield loss

Advantages of leaf color chart

• The LCC is a cheaper method
• Farmers can easily use the Leaf color charts to qualitatively assess foliar N status and adjust N topdressing accordingly
• It helps to manage N for large area leading to improved fertilizer N use efficiency

Average saving in N was 25 kg ha^{-1} by using LCC method without any reduction in yield (Balasubramanian, 2002). LCC at 14 days interval or at critical growth stages of active panicle initiation (PI) and 10 days after active PI would save 40 % of N as compared to blanket recommendation [7]. Higher nitrogen use efficiency of LCC based N management over blanked was reported by Maity and Das (2006) [8]. Shukla *et al*. (2006) from Utter Pradesh noticed that in wheat, LCC threshold value 4 gave higher grain yield, N uptake and NUE than with 120 N kg ha^{-1} applied in 3 fixed time splits [9]. Alam *et al*. (2006) revealed that use of LCC for N management consistently increased the wheat grain yield and added net returns as compared to the farmers' fertilizer practice, in the study conducted at south-western Bangladesh [10]. These studies indicated that for the crop need-based N management using chlorophyll meter or LCC was equally good for inbred and hybrid rice varieties to maximize their yield and NUE. LCC based N management reduced the N fertilizer use by 29 kg ha^{-1} and it also reduced the lodging, pest incidence and production cost of rice [11]. With the help of LCC and SPAD, N could be saved up to 50 and 60 kg ha^{-1}, respectively without yield decrement [12] Maiti *et al*. (2004) reported the mean values of LCC and SPAD varied from 3.19–5.31 and 27.36–39.26, respectively, in rice [13]. The results showed that the amount of N can be saved as 20–42.5 and 27.5–47.5 kg N ha^{-1} through the use of LCC and SPAD in rice over the fixed-timing N treatment, where 150 kg N ha^{-1} was applied in three 3 splits without reduction in the yield. Hussain *et al*. (2005) reported that in rice the nitrogen applied by studying the LCC value at 14 days after panicle initiation and 10 days after panicle initiation would save 40 percent of N as compared to blanket recommendation [14]. Shukla *et al*. (2004) found that NUE can be increased using LCC-based N management without basal N application, provided indigenous soil N supply is sufficiently high (50–60 kg N ha^{-1}). Further they reported a threshold LCC value of 4 for an inbred line (Saket 4) for an optimal yield and NUE in the western Indo-Gangetic plains of India. Jayanthi *et al*. (2007) reported that application of 20kg N ha^{-1} basal + 20 kg N ha^{-1} based on bi-weekly LCC reading at Dharwad (Karnataka) gave the significantly higher yield as compared to farmer's practices due to application of N in more number of splits up to reproductive phase as per LCC guidance was responsible for retaining more number of active leaves till the maturity in the above treatments [15]. Raut (2007) observed in Biswanathpur (Orissa) among the four treatments control (60 Kg N/ha), three times application (60 kg N/ha), N spray based on LCC value ≤ 4 (total nitrogen applied 32 kg N/ha) and N application based on LCC value ≤ 4 (total nitrogen applied 75 kg N/ha) under nitrogen management through LCC [16]. N application based on LCC value ≤ 4 (total nitrogen applied 75 kg N/ha) gave the significantly higher grain yield (4.8t/ha) and straw yield (5.5t/ha) than control (60 Kg N/ha). Sen *et al*. (2011) reported that Leaf color chart based nitrogen management in different rice genotypes save 8.33 % nitrogen as compared to recommended dose of nitrogen application (120 kg N/ha) and gave the highest grain yield 48.33 q/ha (NDR-359) and 42.49 q/ha (Sarju-52), respectively [26]. Gajera *et al*. (2014) reported in Junagadh (Gujarat) LCC based real time N management on grain yield, straw yield and B:C ratio of wheat. Application 30+30 kg N/ha at LCC ≤ 4 gave the significantly higher grain yield (4919 kg/ha) and Straw yield (7048 kg/ha) of wheat.

2) Site-specific nutrient management for nitrogen management

Site-specific nutrient management (SSNM) is the dynamic, field-specific management of nutrients in a particular cropping season to optimize the supply and demand of nutrients according to their differences in cycling through soil-plant systems.

SSNM aims to increase profit through:

• High yield
• High efficiency of fertilizer use
• Providing a locally-adapted nutrient best management practice tailored to the field- and season-specific needs for a crop

What is the site-specific nutrient management approach?

• The site-specific nutrient management (SSNM) approach was developed in Asian rice-producing countries through partnerships of the Irrigated Rice Research Consortium (IRRC).
• It emphasizes 'feeding' crop with nutrients as and when needed.
• SSNM strives to enable farmers to dynamically adjust fertilizer use to optimally fill the deficit between the nutrient needs of a high-yielding crop and the nutrient supply from naturally occurring indigenous sources such as soil, organic amendments, crop residues, manures, and irrigation water.
• The SSNM approach does not specifically aim to either reduce or increase fertilizer use. Instead, it aims to apply nutrients at optimal rates and times to achieve high yield and high efficiency of nutrient use by the crop, leading to high cash value of the harvest per unit of fertilizer invested.

Initial concept of site-specific nutrient management

• The concept of SSNM for rice was developed in the mid-1990s and then evaluated from 1997 to 2000 in about 200 irrigated rice farms at eight sites in six Asian countries.

• SSNM aimed at dynamic field-specific management of N, P, and K fertilizers to optimize the supply and crop demand for nutrients.
• The crop's need for fertilizer N, P, or K was determined from the gap between the crop demand for sufficient nutrient to achieve a yield target and the nutrient supply from indigenous sources.

Use of site specific nutrient management

A. Nutrient use efficiency
-SSNM provides an approach for feeding crop with nutrient as and when needed.
B. Increase profitability
-The major benefit for farmers from improved nutrient management strategy is an increase in the profitability.
-SSNM eliminates wastage of fertilizer by avoiding fertilizer application when the Crop does not require nutrient input.
-It also ensures that N, P and K are applied in the ratio.

A site-specific nutrient management performance in a rice-wheat cropping system reported that site specific management of N gave 20 % higher yield and save 10 % nitrogen in Rice-wheat cropping sequence as compared to Farmers' fertilizer practices(FFP).This increase was attributed to more uniform N applications among sites under SSNM as compared to under FFP [17]. Singh *et al*. (2008) observed that grain yield of rice (unhusked) obtained with SSNM was 8.20 t/ha compared to 6.95 t/ha with the SR (slow release) and 6.03 t/ha with the FP(farmer's practices) [18]. SSNM out-yielded FP by an average of 2.17 t/ha or 36%.The extra yield obtained with rice through SSNM (over FP) ranged from 1 t/ha at Varanasi to 3.27 t/ha at Sabour. This yield advantage with rice was in the order of 25% or more at 7 out of 9 sites. The SSNM treatment out-yielded over FP by more than 2 t/ha at 5 out of 9 locations. Similarly, the rice yield advantages were 3 t/ha or more at Sabour, Faizabad, and Modipuram. Although the SR had a significant edge over FP, the overall response was restricted to only 0.92 t/ha, or 15%.

Chlorophyll meter for nitrogen management

The chlorophyll meter or SPAD meter is a simple, portable diagnostic tool that measures the greenness or relative chlorophyll content of leaves. Meter readings are given in Minolta Company-defined SPAD (Soil Plant Analysis Development) values. There is a strong linear relationship between SPAD values and leaf nitrogen concentration, but this relationship varies with crop growth stage and/or variety. The linear relationship between nitrogen and SPAD values has led to the adaptation of the SPAD meter to assess crop nitrogen status and to determine the plant's need for additional nitrogen fertilizer. SPAD readings indicate that plant nitrogen status and the amount of nitrogen to be applied are determined by the physiological nitrogen requirement of crops at different growth stages.
It is a simple, quick and non-destructive in situ tool for measuring relative content of chlorophyll in leaf that is directly proportional to leaf N content.
The chlorophyll present in the plant is closely related to the nutritional condition of the plant.
Higher SPAD value indicates a healthier plant. A decrease in the SPAD value indicates a decrease in the chlorophyll content and nitrogen concentration; it is show the lack of nitrogen available in the soil. This problem can be solved by adding fertilizer to the soil.

Application

Improve nutrient management.
Study the performance and effect of fertilizer.
Detect and study environmental stressors.
Checking the nutritional condition of plants.

Measuring SPAD values in the field

• SPAD readings are taken at 9-15 days intervals, starting from 14 DAT for transplanted rice and 21 DAS for wet direct seeded rice, Periodic readings continue up to the first (10%) flowering.
• The youngest fully expanded leaf of a plant is used for SPAD measurement.
• Readings are taken on one side of the midrib of the leaf blade.
• A mean of 10-15 readings per field or plot is taken as the measured SPAD value.
• Whenever SPAD values fall below the critical values, N fertilizer should be applied immediately to avoid yield loss.
• Chlorophyll meter based N management in rice reported that chlorophyll based N application of N increase agronomic efficiency 6.97 % over fixed time N application and also save 25 % N as compared to fixed time N application. Singh (2008) reported that no need of basal application of nitrogen only applied 30 kg/ha nitrogen when chlorophyll reading < 37.5 gave higher grain yield of rice over the N30 at SPAD < 35 & N30 basal, N30 at SPAD < 35 & no basal N treatments [19].

Advantages of chlorophyll meter

The chlorophyll meter is faster than tissue testing for N.
Samples can be taken often and can be repeated if results are questionable.
Chlorophyll content can be measured at any time to determine the crop N status.
The chlorophyll meter allows "fine tuning" of N management to field condition.
The Chlorophyll Meter would also help people who are not highly trained to make N recommendations.

Crop canopy sensor for nitrogen management

Crop canopy sensors can be used to estimate crop growth in a population or community rather than individual plant or leaf. It was more efficient and suitable for large scale applications than leaf sensors.

Crop canopy sensors are

Green seeker
Crop circle

Green seeker sensor

Green seeker is emerging as a potential tool for efficient nitrogen management through monitoring crop growth with remotely sensed indices like NDVI (Normalized difference vegetation index).
The GreenSeeker sensor measures normalized difference vegetative index (NDVI) by using a self-illuminated (active sensor) light source in the red and near infrared wavelengths, (660 ± 10 nm) and (780 ± 15 nm), respectively. The Green Seeker calculates NDVI using the following formula:

$$NDVI = \frac{\rho NIR - \rho red}{\rho NIR + \rho red}$$

Where, ρNIR represents the fraction of emitted NIR radiation returned from the sensed area (reflectance) and ρred represents the fraction of emitted red radiation from the sensed area (reflectance). The Green Seeker has an area of measurement of 1 cm × 60 cm when used in a normal operating range of 60 cm to 100 cm over the top of the crop canopy. This sensor collects >10 readings per second and this information were stored in an on-board IPAQ control unit.

Reliability of the Sensor Calibration

The first experiments conducted were to evaluate the reliability of the sensor calibration over time. Pocket sensors readings were taken over a six month period in Ciudad Obregon, Sonora, Mexico, to evaluate sensor performance. To evaluate the calibration, pocket sensor and Green Seeker readings were taken over selected turf grass canopies. The areas measured were small plots that were approximately 1m × 1m. Green Seeker readings were used as the standard value. Each time the calibrations were reviewed, ten locations, representing NDVIvalues from 0.150 to 0.850, were used. Three readings were taken with the Green Seeker sensor, and then three readings were taken with each of the pocket sensors. These data were analyzed using a simple linear regression procedure in SAS (2003), for each sensor for the entire trial period and for each measurement event [20].

Crop canopy sensors

The crop circle sensor is also active and operates under the same principle as that of the green seeker sensor, however the visible light produced by this sensor is called "yellow" by the manufacturer but has also been referred to as the "amber". Therefore, this sensor will be referred to as "amber sensor" and the index calculated will be referred to as "amber index".
Gupta, (2006) reported that use of green shaker saves 25-30 kg N ha^{-1} and 68 kg Nha^{-1} without reduction of grain yield of wheat and rice, respectively [21].

Sapkota *et al*. (2014) observed that application of N @ 154 kg ha^{-1} based on Green shaker gave significantly higher grain yield of wheat compare to other treatments [22]. Singh *et al*. (2010) studied the assessment of the nitrogen management strategy using an optical sensor for irrigated wheat. They reported that use of green shaker gave higher uptake of Total N uptake and save 25-30 kg N ha^{-1} over the farmer's practices.

What is the crop simulation model?

Crop simulation models are quantitative tools based on scientific knowledge that can evaluate the effect of climatic, edaphic, hydrologic and agronomic factors on crop growth and yields.

Crop simulation model groups

1. DSSAT models
2. CERES models
3. WOFOST models
4. Other crop models

Karnade *et al*. (2014) observed that use of the NDVI, NDRE and mSR vegetative indices computed from narrowband spectral reflectance measured using spectro-radiometer are correlated with nitrogen application during booting to flowering period [23]. Hence, these VI can be used to detect the nitrogen stress in wheat crop. The multiple regression and stepwise regression equations were developed to detect nitrogen stress in wheat crop. Stepwise regression analysis revealed that only NDRE is the most sensitive index ($P<0.01$) for nitrogen stress and can be used to judge the nitrogen stress. Using NDRE nitrogen requirement of the crop can be approximated early enough (35-45 DAS) to apply additional fertilizer if necessary. This indicate that, during wheat crop growth if there is any nitrogen stress faced by crop, it can be detected remotely by calculating NDVI, mSR and NDRE vegetative indices at any stage. Though all three indices had correlations with nitrogen applications, but only NDRE showed significantly sensitive index ($P<0.01$) for N deficiency. However if vegetation indices were calculated at very early growth stage (before 35 DAS) the reflectance was more noisy due to contribution of mixed reflectance from soil and crop canopy. Similarly, if vegetation indices were measured at later stage of crop growth (after 50DAS) nitrogen deficiency can be detected but it is not advisable to apply nitrogen at later stages wheat growth in India. In India, recommended dose of 120 kg Nha^{-1} is applied in two split applications *i.e*. 50% at time of sowing and remaining 50% at 30 DAS. If N is applied during later stage (after 50 DAS) it cannot recover physiological stresses imposed by N deficiency during early growth stage. Therefore, timely detection of N deficiency and application of N is most important for getting maximum wheat grain yield especially in precision farming. Hence, NDRE vegetation index measured between 35 to 45 DAS can be used for detecting N deficiency. The correlation, regression and stepwise regression analysis was performed between all vegetation indices and yield of wheat under different N treatments. Statistical analysis revealed that only NDRE showed significant correlation and regression ($P<0.01$) with N applications. Therefore, using NDRE at early growth stage (35-45 DAS) N requirement of the wheat crop can be approximated as early as 35 to 45 DAS using stepwise regression equation with consideration that recommended dose of Nis120 kg N ha^{-1} [24,25]

N = 468.084 - 923.371*NDRE (R2 = 0.78**)

Where,

N = N requirement in kg ha-1 NDRE = NDRE at 35-45 DAS

The model can be used to find out direct N deficiency in wheat in kg N required per hectare.

What does "controlled-release fertilizer" mean?

A controlled-release fertilizer (CRF) is a granulated fertilizer that releases nutrients gradually into the soil.

Terms sometimes used synonymously

Slow-release fertilizer

Delayed-release fertilizer

Three general categories of controlled release fertilizer?

Uncoated, controlled-release

Coated, controlled-release

Bio-inhibitors

–Not really "slow-release" but

–Inhibit microbial processes that convert N into plant available forms and slowly (or relatively slowly) parse N into soil environment

1. Uncoated, slow-release

Urea-formaldehyde reaction products

Isobutylidenediurea (IBDU).

Inorganic salts

2. Coated, slow-release

Sulfur-coated urea

Polymer-coated (or Poly-coated) urea

Neem coated urea

3. Bio-inhibitors

Urease inhibitors

Nitrification inhibitors

Jena *et al*. (2003) studied the effect of Prilled urea and Urea super Granules on Rice yield and agronomic efficiency, result revealed that using urea super granules gave higher NUE as compared to Prilled Urea.

Conclusion

LCC, SPAD meter, SSNM, crop canopy sensor, crop stimulation models and controlled release fertilizers are effective tools of precision N management. Around 10-25 % nitrogen can save through precision nitrogen management.

Application of review: Study applicable for precision farming management

Review Category: Agronomy

Abbreviations:

SSNM: Site specific nutrient management@: at the rate

FPP: farmer's practices

NDVI: Normalized difference vegetative index

LCC: leaf color chart

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