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Improving Rice-wheat cropping system through precision nitrogen management: A review

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Abstract

The rice-wheat cropping system (RWCS) is a major production system in the Indo-Gangetic Plains of India covering nearly 10.5 million hectares including 4.1 million hectares of the northwestern (NW) states comprising Punjab, Haryana, Uttarakhand and western Uttar Pradesh. In India, RW systems account for >80% of the total cereal production and about 50% of the total calorie intake. More than 90% area of the RW area is irrigated and is facing yield stagnation, soil degradation, declining ground water table and air pollution (Singh *et al.*, 2011). Planting techniques are among the important factors affecting soil properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.*, 2006) and affects the sustainable use of soil resources through its influence on soil properties (Lal and Stewart, 2013).Conservation tillage positively influences several aspects of the soil whereas excessive and unnecessary tillage operations give rise to opposite phenomena that are harmful to soil. Therefore, currently there is a significant interest and emphasis on the shift from extreme tillage to conservation and no-tillage methods for the purpose of controlling erosion process (Jill *et al.*, 2011; Naresh *et al.*, 2015).

The human population continues to grow steadily with the shrinking resources being used for agricultural production situates great challenge against Indian agricultural system to attain food and environmental security. To counter these twin challenges in the country there is urgent need of application of modern Hi-tech technologies for enhancing the productivity and sustainability of the rice-wheat system for long term on scientific basis. Precision farming (PF) looks a win-win technology towards improving the capability of agricultural land to produce crops on sustainable basis. The PF is based on the concept of determination of spatial and temporal variability in the crop production which in turn aimed for increasing crop productivity and reducing environmental menaces. It is innovative technology which comprises the application of several Hi-tech tools like Geographical Information System (GIS), Global Positioning System (GPS), Remote Sensing (RS), Variable Rate Technology (VRT), Decision Support System (DSS), and Farmer. Precision land leveling, precision planting, precision nutrient management by using Green Seeker, leaf color chart (LCC), site specific nutrient management has a lot of potential for enhancing crop yield and input use efficiency under field conditions while reducing the cost of production and deleterious impacts on environmental. Among different precision nutrient management practices STCR produced significantly higher grain yield by 13.86 and 33.83% over SPAD and control, respectively, but it remained at par with Green seeker and 100% RDF. N, P, K content and uptake in grain, straw and total as well as protein content were significantly higher with SSNM. However, Amongst N precision management practices, STCR resulted significantly higher N, P and K harvest index and agronomic efficiency, apparent recovery and physiological efficiency except nitrogen physiological efficiency in green seeker. In India, there are wide possibilities to practice a part of PF technologies in rice-wheat system accomplished through the use of simple and inexpensive gadgets like LCCs and expensive gadgets like chlorophyll meter and optical sensors.

Keywords: Precision farming, productivity, rice-wheat cropping system, sustainability

Introduction

Rice–wheat cropping sequence (RWCS) is the world’s largest agricultural production system occupying around 12.3 M ha in India, 0.5 M ha in Nepal, 2.2 M ha in Pakistan and 0.8 M ha in Bangladesh and around 85 percent of this area falls in Indo-Gangetic plains (IGP) (Ladha *et al.*, 2003). The IGP region of India has RWCS spread over a vast area spanning from Punjab in the Northwest to East up to West Bengal (Jat & Sharma, 2005). Sustainability of RWCS system has been questioned with yield stagnation (Ladha *et al.*, 2003; Bhatt & Dulazi, 2015), declining underground water table (Humphreys *et al.*, 2010), unattended intervening periods (Bhatt and Kukal 2015a), soil degradation (Bhandari *et al.*, 2002) and atmospheric pollution (Yadvinder & Buresh, 2008).

The traditional practice for application of production inputs is uniform blanket recommendation across the fields. Several studies have documented that soil properties vary across farm fields, causing spatial variability in crop yields and uniform application of production inputs is not necessarily the most efficient practice (Gaston *et al.*, 2001). Input management using traditional practices wherein application of agricultural inputs for farming are being made irrespective of the resource characteristics have led to low input use efficiency, high cost of production and degradation of natural resources. Precision farming emphasizes the site-specific crop management practices considering the spatial variability of land in order to maximize crop production and minimize environmental damage. Precision farming or site-specific management is an "art and science of utilizing advanced technologies for enhancing crop yield while minimizing environmental threat to the planet", that aimed at managing soil spatial variability by applying inputs in accordance with site-specific requirements of a specific soil and crop. For enhancing the efficiency of farm inputs, increasing productivity and economics of crop production and reducing potential environmental pollution one should ensure to apply farm inputs (i) only when needed, (ii) in specific amounts inputs needed and, (iii) in specific locations of the field which can be ensured through the integration of farmers. Such management practices require quantification of soil spatial variability across the field. Precision farming is not just the use of high-tech equipments, but the acquisition and wise use information obtained from that technology. Today the precision farming technologies viz. yield monitoring, variable rate input application, precision land leveling, and management zone approach, crop input determinations are being studied and adopted in various developed countries of the world. Recently in India, several techniques are being evaluated for precision input management (Sharma *et al.*, 2005). This write-up describes the precision input management technologies (laser land leveling, precision planting, precision nitrogen management using LCC, SPAD, Green Seeker optical sensor, site-specific nutrient management, precision water management etc.) developed and evaluated that have potential role in improving crop productivity and input use efficiency in rice-wheat cropping systems in Indian context.

Why we need to go for precision farming

(i)To increase production efficiency (ii) To improve product quality (iii) Use of chemicals more efficiently (iv) Energy conservation (v) To increase input use efficiency (vi) Soil and ground water protection (vii) Improve soil structure

Major Concerns in Rice–Based Systems

- The decline in soil organic matter (SOM) and depletion of soil nutrients reserves.
- Low nutrient use efficiency (NUE)
- Reduced nutrient cycling.
- Emerging nutrient deficiencies in soil as N, P, Zn, Fe, S, K, Mn, Ca and B.
- Fixation of nutrients in soil particularly of P, K and Zn.
- Imbalanced use of fertilizer
- Nutrient losses due to leaching, runoff, volatilization, denitrification etc.
- Over exploitation of ground water without proper drainage caused soil salinity problem.
- Excessive puddling with improper water management leads to the destruction of soil structure
- Depletion of the ground water table due to excessive exploitation
- Groundwater pollution, especially with No_3 cause blue baby syndrome (methemoglobinemia).

Results and Discussion

Grain yield, straw yield and biological yield

Data pertaining to grain yield, straw yield and biological yield as affected by different precision nutrient management practices and fertility levels of the preceding maize crop have been presented in Table 4.9. The grain yield was significantly increased by SSNM to the tune of 16.72, 27.51 and 128.53% over 100% RDF, 50% RDF and absolute control, respectively. However, significantly higher straw yield was obtained with SSNM over absolute control, but it was statistically at par with 100% RDF and 50% RDF while biological yield was recorded significantly higher by SSNM over absolute control, 50% RDF and 100% RDF but 50% RDF and 100% RDF remained at par with each other. Significantly highest harvest index was found in SSNM over absolute control, 50% RDF; however, it remained at par with 100% RDF. Among different precision nitrogen management practices STCR produced significantly higher grain yield by 13.86 and 33.83% over SPAD and control, respectively, but it remained at par with Green seeker and 100% RDF. While straw yield and biological yield was recorded significantly higher by STCR over control and it remained at par with other remaining precision nutrient management practices. The harvest index was significantly increased by STCR over other precision nitrogen management practices except with RDF. Similar findings were also reported by Mauriya *et al.* (2013) [16], where it was revealed that yield of wheat showed beneficial effects of site-specific nutrient management. Khurana *et al.*, (2008) [11], Singh, (2008) [24] and Mahajan *et al.* (2013) [13] also reported that SSNM significantly increased grain yield.

Nutrient content and uptake

A. Nitrogen content and uptake

Nitrogen content and uptake in grain and straw of wheat was influenced significantly due to various fertility levels and N precision management practices presented in Table 1.

Nitrogen content and uptake in grain and straw was significantly higher with SSNM over absolute control, however nitrogen content in straw and nitrogen uptake by straw remained at par with RDF and 50% RDF. Total N uptake by the plant was significantly higher with SSNM followed by 100% RDF, 50% RDF and absolute control. Protein content also varied significantly with different fertility levels and highest was recorded with SSNM followed by 100% RDF; however 50% RDF and absolute control were at par with each other. It clearly shows that application of balanced fertilization based on target yield resulted significantly higher nitrogen content and uptake by grain and straw. Among N precision management practices significantly higher nitrogen content and uptake by grain and straw and total nitrogen uptake was obtained by STCR followed by Green seeker, 100% RDF and SPAD over absolute control, however 100% RDF and SPAD were at par with respect to nitrogen uptake by the straw. Significantly higher protein content was recorded with STCR due to higher N content of plant. Better timing and splitting of fertilizer N applications during the season was probably the major reason to the increase in N-use efficiency. Khurana *et al.* (2008) [11] also reported significant increases in plant N accumulations with SSNM.

Table 1: Effect of nutrient management practices on nitrogen content and uptake in wheat

Treatments	Nitrogen content (%)		Nitrogen uptake (kg/ha)			Protein content (%)
	Grain	Straw	Grain	Straw	Total	
Control	1.904d	0.342d	41.44d	14.98c	77.11d	10.85d
RDF	2.342bc	0.539bc	64.60b	28.19b	125.46bc	13.35bc
Green seeker	2.465b	0.601b	70.91b)	31.72ab	138.45b	14.05b
SPAD	2.220c	0.521c	56.71c	28.35b	113.30c	12.65c
STCR	2.682a	0.713a	80.30a	36.12a	154.66a	15.29a
LSD(P=0.05)	0.1771	0.0695	11.424	4.962	13.302	1.010

B. Phosphorus content and uptake

Phosphorus content and uptake in grain and straw of wheat was influenced significantly due to various fertility levels and N precision management practices presented in Table 2.

Non-significant effect of nutrient management practices was observed in phosphorus content in straw, but phosphorus content in grain was significantly higher with SSNM over absolute control, however, it remained at par with RDF and 50% RDF. Phosphorus uptake by grain and straw and total uptake was significantly higher with SSNM over absolute control. However phosphorus uptake by straw remained at par with RDF, 50% RDF and SSNM. Among different N precision management practices significant response by phosphorus content and uptake by both grain and straw was observed with STCR. Similarly phosphorus content in straw and phosphorus uptake by straw with STCR and Green seeker were statistically at par with each other. The balanced nutrition with SSNM resulted in higher yield and uptake of phosphorus in wheat. Khurana *et al.* (2008) [11] also reported significant increases in plant P accumulations with SSNM.

Table 2: Effect of nutrient management practices on phosphorus content and uptake in wheat

Treatments	Phosphorus content (%)		Phosphorus uptake (kg/ha)		
Control	10.38d	10.38d	1.27c	10.27e	10.27e
RDF	0.438b	0.053b	18.25b	2.77b	18.66c
Green seeker	0.451b	0.069a	19.47b	3.71a 2	20.79b
SPAD	0.376c	0.041c	14.64c	2.20b	15.21d
STCR	0.526a	0.080a	23.28a	4.08a	25.19a
LSD(P=0.05)	0.03	0.011	1.534	0.787	1.699

C. Potassium content and uptake

Potassium content and uptake in grain and straw of wheat was influenced significantly due to various fertility levels and N precision management practices presented in Table 3.

Potassium content in grain was not affected significantly by various fertility levels, while, significantly higher potassium content in straw was obtained with SSNM, which remained at par with RDF and 50% RDF. Due to higher grain and straw yield significantly higher potassium uptake by grain and straw was obtained with SSNM. However, Potassium uptake by straw and Total Potassium uptake in SSNM remained at par with 100% and 50% RDF. Among different N precision management practices, significantly higher potassium content and uptake in grain and straw and total was obtained with STCR which remained at par with RDF, green seeker and SPAD. Potassium uptake by both grain and straw with STCR was at par with Green seeker. Khurana *et al.* (2008) [11] also reported significant increases in plant K accumulations with SSNM.

Table 3: Effect of nutrient management practices on potassium content and uptake in wheat

Treatments	Potassium content (%)		Potassium uptake (kg/ha)		
Control	0.528b	1.686b	17.46c	72.99b	90.46b
RDF	0.611a	1.888a	25.71ab	98.44a	124.15a
Green seeker	0.606a	1.878a	26.41a	98.96a	125.37a
SPAD	0.598a	1.876a	22.69b	101.73a	124.42a
STCR	0.609a	1.878a	26.77a	95.61a	122.38a
LSD(P=0.05)	0.0666	0.1316	3.498	14.35	15.25

D. Nutrient Harvest Index

The nutrient harvest index of the nutrient shows how nutrient partitioning influenced by agronomic management. Higher index shows more recovery of nutrient in economic yield. The higher dose of recommended potassium by SSNM has influenced the K partitioning in plant. Nutrient harvest index of nitrogen, phosphorus and potassium of wheat was influenced significantly due to various fertility levels. Nitrogen, phosphorus and potassium harvest index was significantly higher in SSNM and lowest in absolute control. Among different N precision management practices, significantly higher nitrogen, phosphorus harvest index was obtained with absolute control, however, harvest index of potassium was not significantly affected by different N precision management practices. The nutrient harvest index was in the order of P, N and K from highest to lowest.

Nutrient Partial Factor Productivity (PFP)

The PFP of any nutrient shows the direct increase in yield with its application. It was in order of K> P > N. Partial factor productivity in Wheat was significantly influenced by different fertility levels and N precision management practices (Table 4). Significantly higher nutrient partial factor productivity (N, P & K) was obtained with SSNM. Among N precision management practices, significantly higher nitrogen PFP was obtained by SPAD, while significantly higher phosphorus PFP was found by RDF, green seeker and SPAD over STCR and significantly higher potassium PFP was found with STCR over RDF, green seeker and SPAD, respectively. Khurana *et al.* (2008) [11] also reported significant increases in partial factor productivity of applied N (PFPN) through the site-specific N management.

Table 4: Effect of nutrient management practices on nutrients Partial Factor Productivity (PFP) of nutrient applied in wheat

Treatments	PFP (kg grain/kg nutrient applied)		
	Nitrogen	Phosphorus	Potassium
Control	-	-	-
RDF	34.5c	69.0a	103.5b
Green seeker	39.0b	71.8a	107.7b
SPAD	42.4a	63.6a	95.3b
STCR	31.4d	67.9b	775.5a
LSD(P=0.05)	2.21	4.19	33.02

Agronomic Efficiency (AE)

The increase in the yield over control plot explained by the AE of any nutrient which is one of good measure for efficiency of nutrient application estimation. Agronomic efficiency in Wheat was significantly influenced by different fertility levels and N precision management practices. Significantly higher nitrogen, phosphorus and potassium agronomic efficiency was obtained with SSNM whereas lowest was found with 100% RDF. It clearly shows that balanced application in the form of SSNM resulted in significantly higher nitrogen, phosphorus and potassium agronomic efficiency because of higher grain yield produced by SSNM. Among N precision management practices Green seeker produced significantly higher nitrogen and phosphorus agronomic efficiency whereas significantly higher potassium agronomic efficiency was found with STCR. Agronomic efficiency of the applied nutrient was in the order of K>P>N. Amount of the nutrient applied is inversely related to agronomic efficiency. Due to this reason lower AE was observed compared to K & P. Similar result was also observed by Gilkes *et al.*(2010) [7], where SSNM increased the agronomic efficiency of N fertilizer by 53% compared to the Farmer Fertilizer Practices (FFP). Pasuquin *et al.* (2010) [18] also found that SSNM increased the agronomic efficiency of N fertilizer by 53% compared to the FFP and average AEN under SSNM rose to 25.1 kg/kg, an increase of 53% compared to the FFP. Better timing and splitting of fertilizer N applications during the season was probably the major reason to the increase in N-use efficiency.

Apparent Nutrient Recovery

The recovery of any nutrient applied shows the soil supplying capacity and the inherent capacity of the plant to utilize nutrient. It is also dependent on the growing environment and method of application. Apparent nutrient recovery in wheat was significantly influenced by different fertility levels and N precision management practices. The potassium recovery of the crop was more than 100% of the applied nutrient which was due to high level of K in the soil in addition to lower K fertilizer doses. Application of SSNM resulted significantly higher nitrogen and phosphorus apparent recovery, whereas different fertility levels had no significant effect on potassium apparent recovery, though highest potassium apparent recovery was recorded with SSNM. Because of balanced application of nutrients by SSNM, significantly higher apparent recovery (% nutrient applied) was obtained as all of these nutrients are synergistic in nature. Among N precision management practices STCR resulted significantly higher apparent recovery (N, P & K). However, nitrogen apparent recovery was found at par with Green seeker.

Physiological Efficiency (PE)

The PE of the nutrient shows the utilization capacity of the plant nutrient uptake. The higher the efficiency indicates more capacity of plant to increase yield with per unit nutrient uptake. Physiological efficiency in wheat was significantly influenced by different fertility levels and N precision management practices. Significantly higher nitrogen and phosphorus physiological efficiency was obtained with SSNM. The potassium physiological efficiency was not significantly influenced by different fertility levels, however potassium physiological efficiency was found highest with SSNM. It shows clearly that balanced application of nutrient by SSNM increased physiological efficiency significantly. Among N precision management practices, Green seeker produced significantly higher nitrogen physiological efficiency and STCR produced significantly higher phosphorus and potassium physiological efficiency, respectively. Mahajan *et al.* (2013) [13] also reported STCR-IPNS technology ensures higher nutrient use efficiencies.

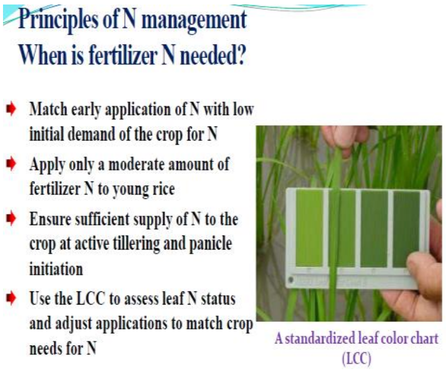
Economics

The economic considerations are the deciding factor for any technology to be adopted by farmers. In this regard each treatments economic analysis has been studied. Data pertaining to cost of cultivation, gross and net return and B: C ratio as affected by different precision nutrient management practices and fertility levels of the preceding maize crop have been presented in Table 10. Same cost of cultivation was observed in all the fertility levels. Significantly highest gross return (` 80052), net return (` 55308) and B C ratio (2.23) was obtained with SSNM over 100% RDF, 50% RDF and absolute control. Among different precision nutrient management practices maximum cost of cultivation was found in 100% RDF while maximum gross return (` 68528) was found in Green seeker which is statistically at par with STCR (` 68434). Net return was highest (` 42724) in STCR which was statistically at par with Green seeker (` 42525). However, benefit cost ratio was found to be highest (1.66) with STCR which also was statistically at par with Green seeker (1.64) and lowest with SPAD (1.43). Pampolino *et al.* (2012b) [17] also found in wheat that gross return above fertilizer costs (GRF) were significantly higher with Nutrient Expert than State Recommendation and Farmers Field Practice. Highest net returns were obtained with SSNM treatment (Mauriya *et al.*, 2013) [16]. Yadav and Kumar (2009) [29] also reported similar results from rice-wheat system using site-specific nutrient management. Mahajan *et al.* (2013) [13] also reported STCR-IPNS technology ensures higher profitability. Similarly B: C ratio was higher in STCR approach in wheat over general recommended dose and control (Keram *et al.*, 2012) [10].

Real-time site-specific N management using non-invasive optical methods

Substantial portions of applied N are lost due to the lack of synchrony of plant–N demand with N supply. The timing of fertilizer N application is used to best match the demand of N by crop plants with supply. In mid-1980s and 1990s, the emphasis was shifted from reducing N losses to feeding crop needs for increasing fertilizer N use efficiency (Buresh, 2007) [30]. The research was oriented towards finding means and ways to apply fertilizer N in real time using crop- and field-specific needs. Several methods based on soil tests and analyses of tissue samples were tried to predict cereal N needs during vegetative growth stages. These studies showed good correlations with grain yield and acceptable levels of accuracy; however, soil and tissue tests were time consuming, cumbersome and expensive. Moreover, the prospects remained bleak for accurate N prescriptions developed using soil tests before the season (Han *et al.*, 2002). Tissue tests were also of limited value for predicting fertilizer N needs because a period of 10–14 days from sampling to receiving a fertilizer recommendation dose does not seem a practical proposition. Thus, most farmers use leaf colour as a visual and subjective indicator of the need for N fertilizer, although visual estimate of leaf colour is influenced by sunlight variability and is a non-quantitative method for determining the N needs of rice.

An important element of site-specific N management is the development and use of diagnostic tools that can assess ‘real-time’ N need of crop plants (Fageria and Baligar, 2005). The concept of using spectral ratio reflectance to rapidly quantify colour of intact plant leaves appears to have originated with Inada. This concept is based on the assumption that spectral characteristics of radiation reflected, transmitted or absorbed by leaves can provide a better indication of plant chlorophyll content. The grain yield was 2.80 per cent higher in treatment where N fertilizer applied as per leaf colour chart. The results showed that the farmers can achieve the grain yield by N management using leaf colour chart. However, several other experimenter reported higher grain yield of rice at LCC 4 and suggested for adoption of LCC 4 to be optimum value for real time N management considering higher grain yield and N saving (Budhar, 2005; Balaji and Jawahar, 2007; Sathiya and Ramesh, 2009) [3, 1]

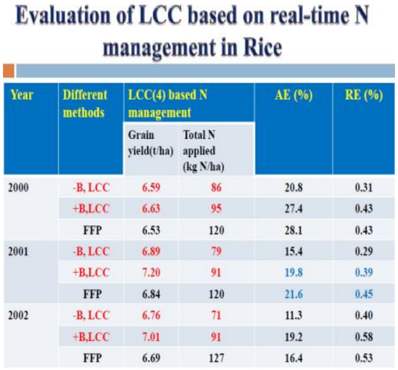


Principles of N management

When is fertilizer N needed?

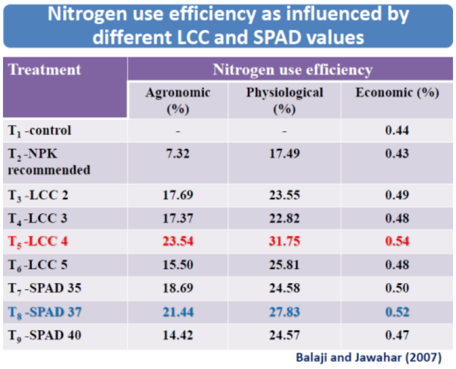
- Match early application of N with low initial demand of the crop for N
- Apply only a moderate amount of fertilizer N to young rice
- Ensure sufficient supply of N to the crop at active tillering and panicle initiation
- Use the LCC to assess leaf N status and adjust applications to match crop needs for N

A standardized leaf color chart (LCC)



Evaluation of LCC based on real-time N management in Rice

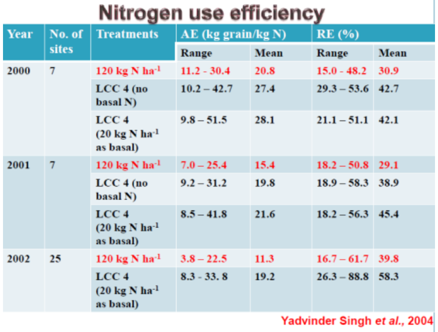
Year	Different methods	LCC(4) based N management		AE (%)	RE (%)
		Grain yield(t/ha)	Total N applied (kg N/ha)		
2000	-B, LCC	6.59	86	20.8	0.31
	+B,LCC	6.63	95	27.4	0.43
	FFP	6.53	120	28.1	0.43
2001	-B, LCC	6.89	79	15.4	0.29
	+B,LCC	7.20	91	19.8	0.39
	FFP	6.84	120	21.6	0.45
2002	-B, LCC	6.76	71	11.3	0.40
	+B,LCC	7.01	91	19.2	0.58
	FFP	6.69	127	16.4	0.53



Nitrogen use efficiency as influenced by different LCC and SPAD values

Treatment	Nitrogen use efficiency		
	Agronomic (%)	Physiological (%)	Economic (%)
T_1 -control	-	-	0.44
T_2 -NPK recommended	7.32	17.49	0.43
T_3 -LCC 2	17.69	23.55	0.49
T_4 -LCC 3	17.37	22.82	0.48
T_5 -LCC 4	23.54	31.75	0.54
T_6 -LCC 5	15.50	25.81	0.48
T_7 -SPAD 35	18.69	24.58	0.50
T_8 -SPAD 37	21.44	27.83	0.52
T_9 -SPAD 40	14.42	24.57	0.47

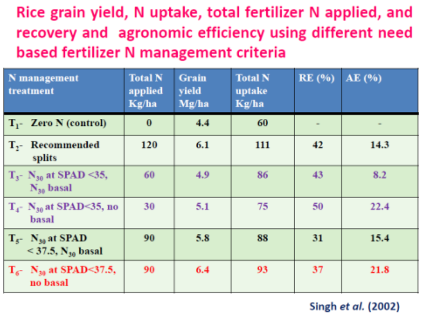
Balaji and Jawahar (2007)



Nitrogen use efficiency

Year	No. of sites	Treatments	AE (kg grain/kg N)		RE (%)	
			Range	Mean	Range	Mean
2000	7	120 kg N ha^{-1}	11.2 - 30.4	20.8	15.0 - 48.2	30.9
		LCC 4 (no basal N)	10.2 – 42.7	27.4	29.3 – 53.6	42.7
		LCC 4 (20 kg N ha^{-1} as basal)	9.8 – 51.5	28.1	21.1 – 51.1	42.1
2001	7	120 kg N ha^{-1}	7.0 – 25.4	15.4	18.2 – 50.8	29.1
		LCC 4 (no basal N)	9.2 – 31.2	19.8	18.9 – 58.3	38.9
		LCC 4 (20 kg N ha^{-1} as basal)	8.5 – 41.8	21.6	18.2 – 56.3	45.4
2002	25	120 kg N ha^{-1}	3.8 – 22.5	11.3	16.7 – 61.7	39.8
		LCC 4 (20 kg N ha^{-1} as basal)	8.3 - 33. 8	19.2	26.3 – 88.8	58.3

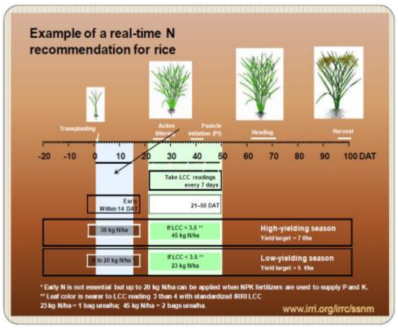
Yadvinder Singh *et al.*, 2004



Rice grain yield, N uptake, total fertilizer N applied, and recovery and agronomic efficiency using different need based fertilizer N management criteria

N management treatment	Total N applied Kg/ha	Grain yield Mg/ha	Total N uptake Kg/ha	RE (%)	AE (%)
T_1- Zero N (control)	0	4.4	60	-	-
T_2- Recommended splits	120	6.1	111	42	14.3
T_3- N_{30} at SPAD <35, N_{30} basal	60	4.9	86	43	8.2
T_4- N_{30} at SPAD<35, no basal	30	5.1	75	50	22.4
T_5- N_{30} at SPAD < 37.5, N_{30} basal	90	5.8	88	31	15.4
T_6- N_{30} at SPAD<37.5, no basal	90	6.4	93	37	21.8

Singh *et al.* (2002)



Example of a real-time N recommendation for rice

* Early N is not essential but up to 20 kg N/ha can be applied when NPK fertilizers are used to supply P and K.

** Leaf color is nearer to LCC reading 3 than 4 with standardized IRRI LCC

23 kg N/ha = 1 bag urea/ha; 45 kg N/ha = 2 bags urea/ha.

www.irri.org/irrc/ssnm

SPAD reading

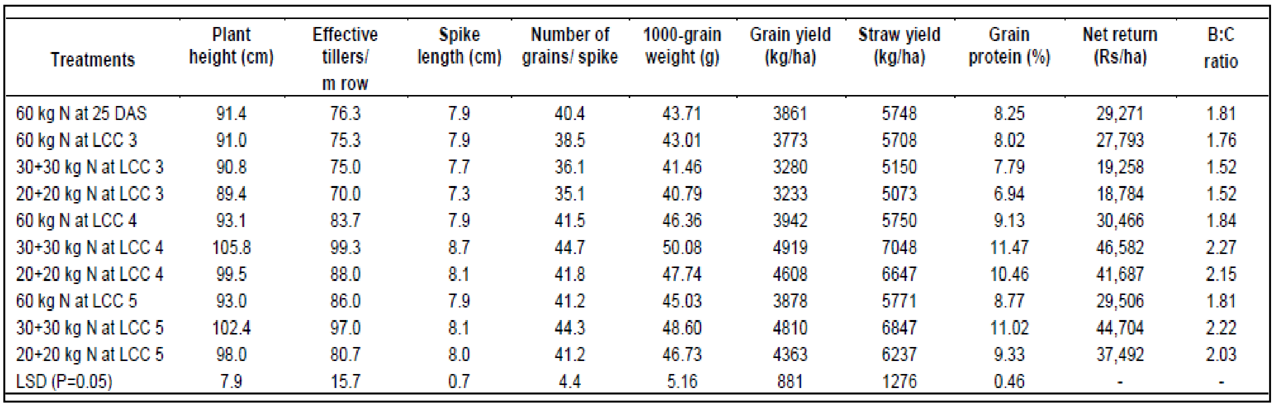
The SPAD meter is a simple portable diagnostic tool used for monitoring crop N status in situ in the field. To achieve the maximum yield target, the N concentration of the upper most fully expanded leaf must be maintained at or above 1.4 g N/m^2 (leaf area basis). Leaf N status at this critical level gives a SPAD value of 35 regardless of genotypes (Dobermann and Fairhurst, 2000) [6]. The SPAD reading was taken by a chlorophyll meter (SPAD-502, Minolta Camera Co., Japan). The LCC is a plastic scale with a green colour gradient from 1 to 6 (very light green to dark green) by which greenness of rice leaves can be measured. Data for SPAD and LCC values were collected from the same leaves from 20 DAT at 7-day intervals up to 50% flower initiation. The SPAD and LCC readings were taken from the middle portion of the fully expanded youngest leaves from 5 randomly selected hills. When the SPAD reading came down to critical value 35, corresponding LCC value was considered as critical LCC value of that variety.

Effect on growth and yield

Real time application of 60 kg N/ha in two equal splits at LCC 4, being at par with application of 60 kg N/ha in two equal splits at LCC 5, significantly improved growth and yield attributes like plant height, number of effective tillers/m row length, spike length, number of grains/spike and 1000-grain weight compared to that in fixed time application of 60 kg N/ha (Table 7). This could be attributed to better synchronization of N supply with crop N demand leading to higher N uptake due to real time application of 60 kg N/ha in two equal splits at LCC 4. It is assumed that better nutrition, as indicated by higher leaf N content, improved photosynthetic rate when 60 kg N/ha was applied in two equal splits at LCC 4 over fixed time application of 60 kg N/ha at 25 DAS. Improvement in leaf chlorophyll content due to application of 60 kg N/ha in two equal splits at LCC 4 over fixed time application of 60 kg N/ha at 25 DAS supports improved photosynthetic rate leading to higher growth and biomass production.

The enhanced growth with LCC based nitrogen application was also reported by Singh *et al.* (2002) and Shukla *et al.* (2004) [22]. Real time application of 60 kg N/ha in two equal splits at LCC 4 significantly increased grain (4919 kg/ha) and straw yield (7048 kg/ha) of wheat as compared to fixed time application of 60 kg N/ha at 25 DAS (Table 7). Real time application of 60 kg N/ha in two equal splits at LCC 4 increased grain and straw yield by 27.40 and 22.61% respectively over fixed time application of 60 kg N/ha at 25DAS. The significant increase in growth and biomass production due to real time N management get reflected into significant increase in yield attributes and yield of wheat. These results confirm the findings of Maiti and Das (2006) [15] and Shukla *et al.* (2004) [22]. In case of treatment 60 kg N/ha in two equal splits at LCC 4, which gave significantly highest yield, the split application of N was given at 52 and 66 days after sowing. This indicates the need for revisiting the conventional N fertilizer recommendation of split dose of 60 N/ha at 21 days after sowing.

Table 5: Effect of LCC based real time N management on growth attributes, leaf N content and leaf chlorophyll content in wheat (Pooled over two years).



Treatments	Plant height (cm)	Effective tillers/ m row	Spike length (cm)	Number of grains/ spike	1000-grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Grain protein (%)	Net return (Rs/ha)	B:C ratio
60 kg N at 25 DAS	91.4	76.3	7.9	40.4	43.71	3861	5748	8.25	29,271	1.81
60 kg N at LCC 3	91.0	75.3	7.9	38.5	43.01	3773	5708	8.02	27,793	1.76
30+30 kg N at LCC 3	90.8	75.0	7.7	36.1	41.46	3280	5150	7.79	19,258	1.52
20+20 kg N at LCC 3	89.4	70.0	7.3	35.1	40.79	3233	5073	6.94	18,784	1.52
60 kg N at LCC 4	93.1	83.7	7.9	41.5	46.36	3942	5750	9.13	30,466	1.84
30+30 kg N at LCC 4	105.8	99.3	8.7	44.7	50.08	4919	7048	11.47	46,582	2.27
20+20 kg N at LCC 4	99.5	88.0	8.1	41.8	47.74	4608	6647	10.46	41,687	2.15
60 kg N at LCC 5	93.0	86.0	7.9	41.2	45.03	3878	5771	8.77	29,506	1.81
30+30 kg N at LCC 5	102.4	97.0	8.1	44.3	48.60	4810	6847	11.02	44,704	2.22
20+20 kg N at LCC 5	98.0	80.7	8.0	41.2	46.73	4363	6237	9.33	37,492	2.03
LSD (P=0.05)	7.9	15.7	0.7	4.4	5.16	881	1276	0.46	-	-

Source: Mathukia *et al.* (2014) Agricultural University, Junagadh- Gujarat

Effect on quality

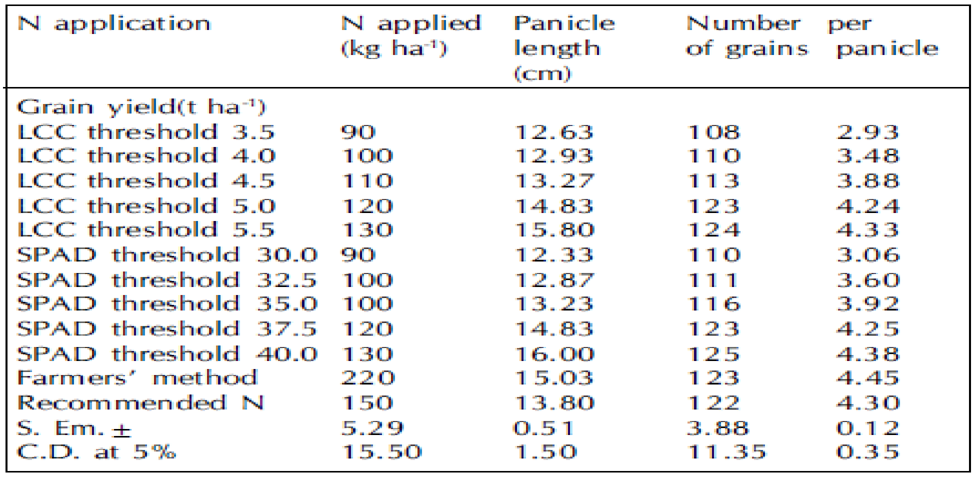
Real time application of 60 kg N/ha in two equal splits at LCC 4 significantly increased grain protein content (11.47 %) over fixed time application of 60 kg N/ha at 25 DAS (Table 7). This could be explained on the basis of better availability of N in the crop root zone and enhanced N uptake and consequent increase in photosynthetic and metabolic activities resulting in better partitioning of photosynthates to sinks, which got reflected in quality enhancement in terms of grain protein content and protein yield. Quality of food grains is a complex phenomenon and may be influenced by both genetic and/or environmental factors.

Effect on economic returns

While there was negligible increase in cost of cultivation due to real time application of 60 kg N/ha in two equal splits at LCC 4 but, it increased net returns (Rs. 46,582/ha) by 59.14% over fixed time application of 60 kg N/ha at 25 DAS (Table). The B: C ratio also improved to 2.27 due to real time application of 60 kg N/ha in two equal splits at LCC 4 from 1.81 in fixed time application of 60 kg N/ha at 25 DAS. Dineshkumar (2011) has also reported higher net returns and B: C ratio with LCC based real time N management.

The data on yield components (panicle length, number of grains panicle^{-1} and grain yield of rice as influenced by different treatments are furnished in Table 6 & 7. All the yield parameters and grain yield were favorably influenced when N was applied under LCC and SPAD guidance especially at higher rate i.e., 20 or 30 kg N ha^{-1} per application. Adequate N supply during reproductive growth phase was probably responsible in enhancing yield parameters and in turn the yield. The maximum yield of 4.4 t ha^{-1} was recorded in SPAD-40 threshold valve (30 kg N ha^{-1} basal + 100 kg N ha^{-1} based on weekly SPAD reading), but it was statistically on par with the yield recorded in Farmers and recommended practice with saving of 40 and 13% N, respectively. Balasubramanian *et al.* (1999) observed increase in growth and yield parameters with the SPAD based N application. The application of N @ 90 & 100 kg ha^{-1} per application under LCC guidance accounted for lower values of yield parameters which could be attributed to inadequate N to meet the crop needs. Kumar *et al.* (2000) and stalin *et al.* (2000) described the increased grain yield to the combined favorable effects of improved leaf N concentration, photosynthetic rate of flag leaves and increased filled grain percentage. Kenchaiah *et al.* (2000) also found higher grain yield under LCC based N management than the blanket recommendation.

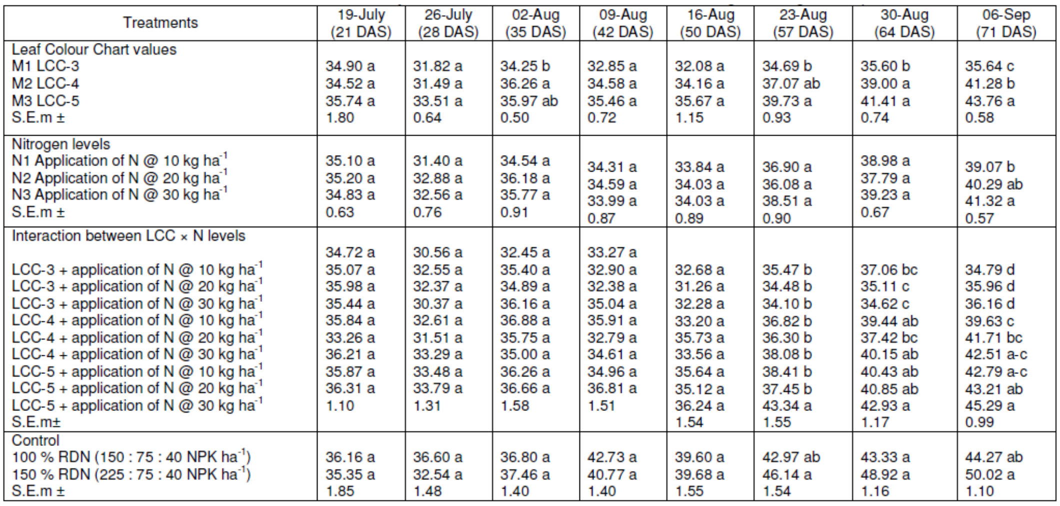
Table 6: Effect of N application on days to 50% flowering, yield and yield parameters as influenced by N management



N application	N applied (kg ha^{-1})	Panicle length (cm)	Number of grains	per panicle
Grain yield(t ha^{-1})				
LCC threshold 3.5	90	12.63	108	2.93
LCC threshold 4.0	100	12.93	110	3.48
LCC threshold 4.5	110	13.27	113	3.88
LCC threshold 5.0	120	14.83	123	4.24
LCC threshold 5.5	130	15.80	124	4.33
SPAD threshold 30.0	90	12.33	110	3.06
SPAD threshold 32.5	100	12.87	111	3.60
SPAD threshold 35.0	100	13.23	116	3.92
SPAD threshold 37.5	120	14.83	123	4.25
SPAD threshold 40.0	130	16.00	125	4.38
Farmers' method	220	15.03	123	4.45
Recommended N	150	13.80	122	4.30
S. Em. ±	5.29	0.51	3.88	0.12
C.D. at 5%	15.50	1.50	11.35	0.35

Source: Shantappa *et al.* (2014) Raichur, Karnataka

Table 7: SPAD meter values of maize as influenced by leaf colour chart values and N levels at different growth stages of crop

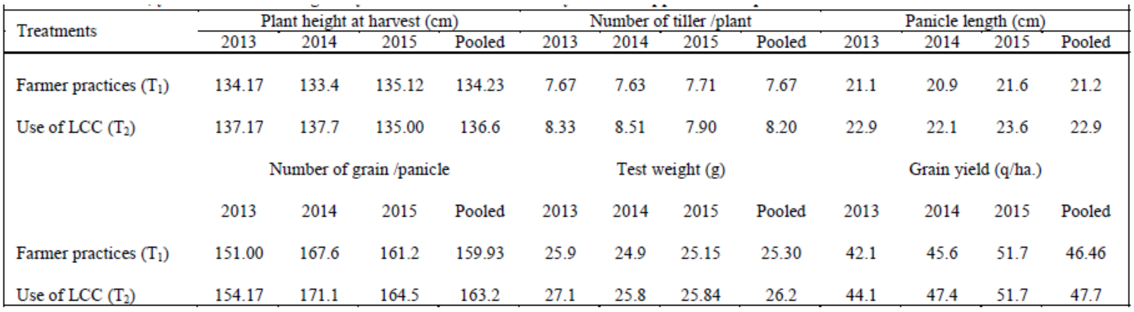


Treatments	19-July (21 DAS)	26-July (28 DAS)	02-Aug (35 DAS)	09-Aug (42 DAS)	16-Aug (50 DAS)	23-Aug (57 DAS)	30-Aug (64 DAS)	06-Sep (71 DAS)
Leaf Colour Chart values								
M1 LCC-3	34.90 a	31.82 a	34.25 b	32.85 a	32.08 a	34.69 b	35.60 b	35.64 c
M2 LCC-4	34.52 a	31.49 a	36.26 a	34.58 a	34.16 a	37.07 ab	39.00 a	41.28 b
M3 LCC-5	35.74 a	33.51 a	35.97 ab	35.46 a	35.67 a	39.73 a	41.41 a	43.76 a
S.E.m ±	1.80	0.64	0.50	0.72	1.15	0.93	0.74	0.58
Nitrogen levels								
N1 Application of N @ 10 kg ha^{-1}	35.10 a	31.40 a	34.54 a	34.31 a	33.84 a	36.90 a	38.98 a	39.07 b
N2 Application of N @ 20 kg ha^{-1}	35.20 a	32.88 a	36.18 a	34.59 a	34.03 a	36.08 a	37.79 a	40.29 ab
N3 Application of N @ 30 kg ha^{-1}	34.83 a	32.56 a	35.77 a	33.99 a	34.03 a	38.51 a	39.23 a	41.32 a
S.E.m ±	0.63	0.76	0.91	0.87	0.89	0.90	0.67	0.57
Interaction between LCC × N levels								
LCC-3 + application of N @ 10 kg ha^{-1}	34.72 a	30.56 a	32.45 a	33.27 a	32.68 a	35.47 b	37.06 bc	34.79 d
LCC-3 + application of N @ 20 kg ha^{-1}	35.07 a	32.55 a	35.40 a	32.90 a	31.26 a	34.48 b	35.11 c	35.96 d
LCC-3 + application of N @ 30 kg ha^{-1}	35.98 a	32.37 a	34.89 a	32.38 a	32.28 a	34.10 b	34.62 c	36.16 d
LCC-4 + application of N @ 10 kg ha^{-1}	35.44 a	30.37 a	36.16 a	35.04 a	33.20 a	36.82 b	39.44 ab	39.63 c
LCC-4 + application of N @ 20 kg ha^{-1}	35.84 a	32.61 a	36.88 a	35.91 a	35.73 a	36.30 b	37.42 bc	41.71 bc
LCC-4 + application of N @ 30 kg ha^{-1}	33.26 a	31.51 a	35.75 a	32.79 a	33.56 a	38.08 b	40.15 ab	42.51 a-c
LCC-5 + application of N @ 10 kg ha^{-1}	36.21 a	33.29 a	35.00 a	34.61 a	35.64 a	38.41 b	40.43 ab	42.79 a-c
LCC-5 + application of N @ 20 kg ha^{-1}	35.87 a	33.48 a	36.26 a	34.96 a	35.12 a	37.45 b	40.85 ab	43.21 ab
LCC-5 + application of N @ 30 kg ha^{-1}	36.31 a	33.79 a	36.66 a	36.81 a	36.24 a	43.34 a	42.93 a	45.29 a
S.E.m±	1.10	1.31	1.58	1.51	1.54	1.55	1.17	0.99
Control								
100 % RDN (150 : 75 : 40 NPK ha^{-1})	36.16 a	36.60 a	36.80 a	42.73 a	39.60 a	42.97 ab	43.33 a	44.27 ab
150 % RDN (225 : 75 : 40 NPK ha^{-1})	35.35 a	32.54 a	37.46 a	40.77 a	39.68 a	46.14 a	48.92 a	50.02 a
S.E.m ±	1.85	1.48	1.40	1.40	1.55	1.54	1.16	1.10

Source: Sarnaik, (2010) Dharwad, Karnataka

Sarnaik, (2010) reported that the leaf photosynthetic rate and leaf N concentration were closely related in rice and hence maintaining adequate leaf N throughout the growing period was crucial for achieving high yield. They concluded that LCC based N management was better than recommended practice.

Table 8: Growth, yield attributes and grain yield of rice as influenced by use of N application as per leaf colour chart in rice crop

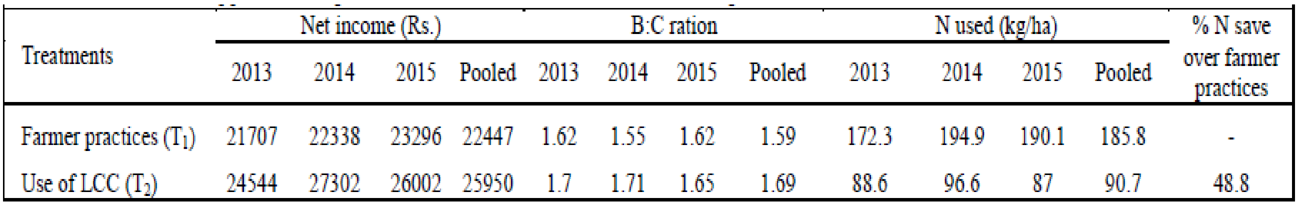


Treatments	Plant height at harvest (cm)				Number of tiller /plant				Panicle length (cm)			
	2013	2014	2015	Pooled	2013	2014	2015	Pooled	2013	2014	2015	Pooled
Farmer practices (T_1)	134.17	133.4	135.12	134.23	7.67	7.63	7.71	7.67	21.1	20.9	21.6	21.2
Use of LCC (T_2)	137.17	137.7	135.00	136.6	8.33	8.51	7.90	8.20	22.9	22.1	23.6	22.9
	Number of grain /panicle				Test weight (g)				Grain yield (q/ha.)			
	2013	2014	2015	Pooled	2013	2014	2015	Pooled	2013	2014	2015	Pooled
Farmer practices (T_1)	151.00	167.6	161.2	159.93	25.9	24.9	25.15	25.30	42.1	45.6	51.7	46.46
Use of LCC (T_2)	154.17	171.1	164.5	163.2	27.1	25.8	25.84	26.2	44.1	47.4	51.7	47.7

Source: Singh and Sharma, (2016) K.V.K. Kheda, Gujarat

The pooled data on various growth parameters (Table 8) indicated that plant height was higher in T_2 on pooled basis due to steady supply of N applied at seedling stage helped to produce favorable effect on growth attributes. Among the treatments, T_2 (use N fertilizer as per LCC) recorded higher tiller per plant on pooled basis and it was 6.49 per cent higher than farmer practices. Panicle length, number of grain per panicle and test weight at harvest was recorded higher in T_2 as compared to T_1. The grain yield was 2.80 per cent higher in treatment where N fertilizer applied as per leaf colour chart. The results showed that the farmers can achieve the grain yield by N management using leaf colour chart. However, several other experimenter reported higher grain yield of rice at LCC 4 and suggested for adoption of LCC 4 to be optimum value for real time N management considering higher grain yield and N saving (Budhar, 2005; Balaji and Jawahar, 2007) [3, 1].

Table 9: Effect of N application as per leaf colour chart on economics in rice crop



Treatments	Net income (Rs.)				B:C ration				N used (kg/ha)				% N save over farmer practices
	2013	2014	2015	Pooled	2013	2014	2015	Pooled	2013	2014	2015	Pooled	
Farmer practices (T_1)	21707	22338	23296	22447	1.62	1.55	1.62	1.59	172.3	194.9	190.1	185.8	-
Use of LCC (T_2)	24544	27302	26002	25950	1.7	1.71	1.65	1.69	88.6	96.6	87	90.7	48.8

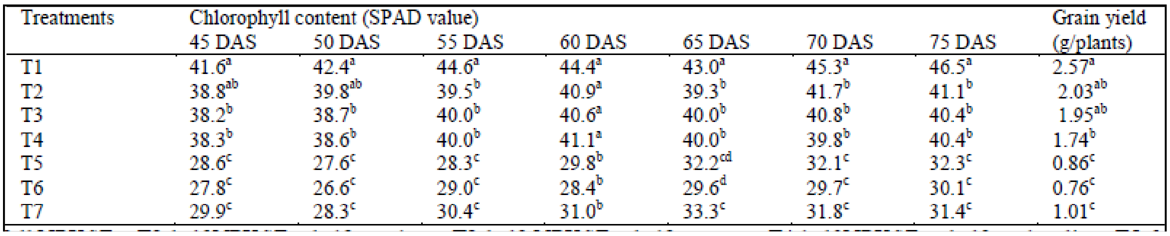
Source: Singh and Sharma, (2016) K.V.K.Kheda,Gujarat

The data in Table 9 revealed that paddy under treatment recorded 15.6 per cent higher net return (Rs. 25950 /ha) and B: C. ratio (1:1.69) as compared to the local check where farmers got net returns and B: C ratio of Rs. 22447/ ha and 1:1.59 on pooled basis, respectively. Similar finding also reported by Raddy and Pattar (2006) that the leaf colour chart appeared to be an easy and inexpensive tool for efficient N management in irrigated transplanted rice. The leaf colour chart based application of N recorded higher grain yield and net returns besides resulting in greater savings in fertilizer N and can be easily adopted by famers.

The SPAD or chlorophyll meter value and grain yield data of wheat are illustrated in Table 10. Irrespective of fertilizer management options, the SPAD values showed an increasing trend with the advance of plant growth. The SPAD values varied from 26.6-46.5 among different fertilizer treatments.

The values were higher (>41.6) in treatment receiving full dose of NPKS Zn through inorganic fertilizers as compared with reduced inorganic fertilizers and/or organically supplied fertilizers. However, the values remarkably decreased and varied from 38.2-41.7 in treatments supplied with half dose inorganic fertilizers and full organic fertilizers. The SPAD values drastically reduced ranging from 26.6-33.3 in treatments treated with only organic fertilizers. The grain yield had similar trends with the SPAD values estimated for variable fertilizer application. The highest grain yield was obtained in plants treated with full amount of inorganic fertilizers. Reducing inorganic fertilizers and organic amendments also reduced wheat yield to some extent. However, a significantly greater gain yield reduction was occurred in treatments using sole organic fertilizers. This might be due to the fact that N supply in organic treatment is generally restricted for slow N mineralization as compared to crop N demands (Maiti and Das, 2006) [15].

Table 10: Leaf chlorophyll content (SPAD value) at different growth stages of wheat and observed grain yield



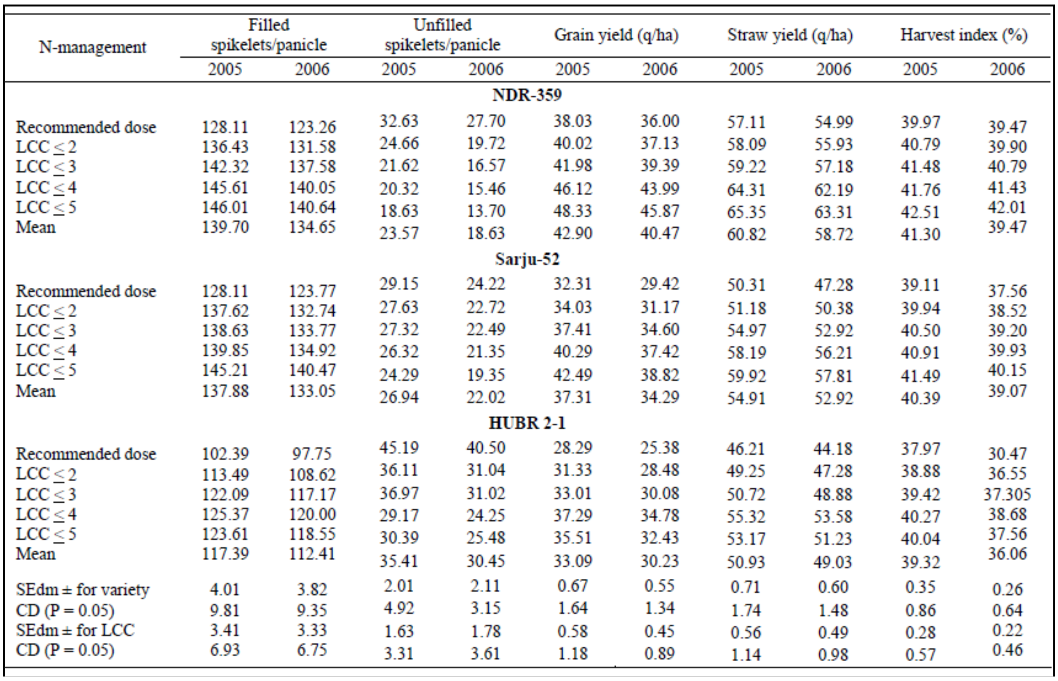
Treatments	Chlorophyll content (SPAD value)							Grain yield
	45 DAS	50 DAS	55 DAS	60 DAS	65 DAS	70 DAS	75 DAS	(g/plants)
T1	41.6^{a}	42.4^{a}	44.6^{a}	44.4^{a}	43.0^{a}	45.3^{a}	46.5^{a}	2.57^{a}
T2	38.8^{ab}	39.8^{ab}	39.5^{b}	40.9^{a}	39.3^{b}	41.7^{b}	41.1^{b}	2.03^{ab}
T3	38.2^{b}	38.7^{b}	40.0^{b}	40.6^{a}	40.0^{b}	40.8^{b}	40.4^{b}	1.95^{ab}
T4	38.3^{b}	38.6^{b}	40.0^{b}	41.1^{a}	40.0^{b}	39.8^{b}	40.4^{b}	1.74^{b}
T5	28.6^{c}	27.6^{c}	28.3^{c}	29.8^{b}	32.2^{cd}	32.1^{c}	32.3^{c}	0.86^{c}
T6	27.8^{c}	26.6^{c}	29.0^{c}	28.4^{b}	29.6^{d}	29.7^{c}	30.1^{c}	0.76^{c}
T7	29.9^{c}	28.3^{c}	30.4^{c}	31.0^{b}	33.3^{c}	31.8^{c}	31.4^{c}	1.01^{c}

T$_1$-full NPKSZn; **T$_2$**-half NPKSZn+half cowdung; **T$_3$**-half NPKSZn+half compost; **T$_4$**-half NPKSZn+ half poultry liter; **T$_5$**-full cowdung; **T$_6$**-full dose compost; **T$_7$**-full dose poultry liter.

Means in rows followed by the same letter are not significantly different at the 5% level.

Source: Islam *et al.* (2014) [8]

Table 11: Effect of treatments on the yield and yield attributes of rice.

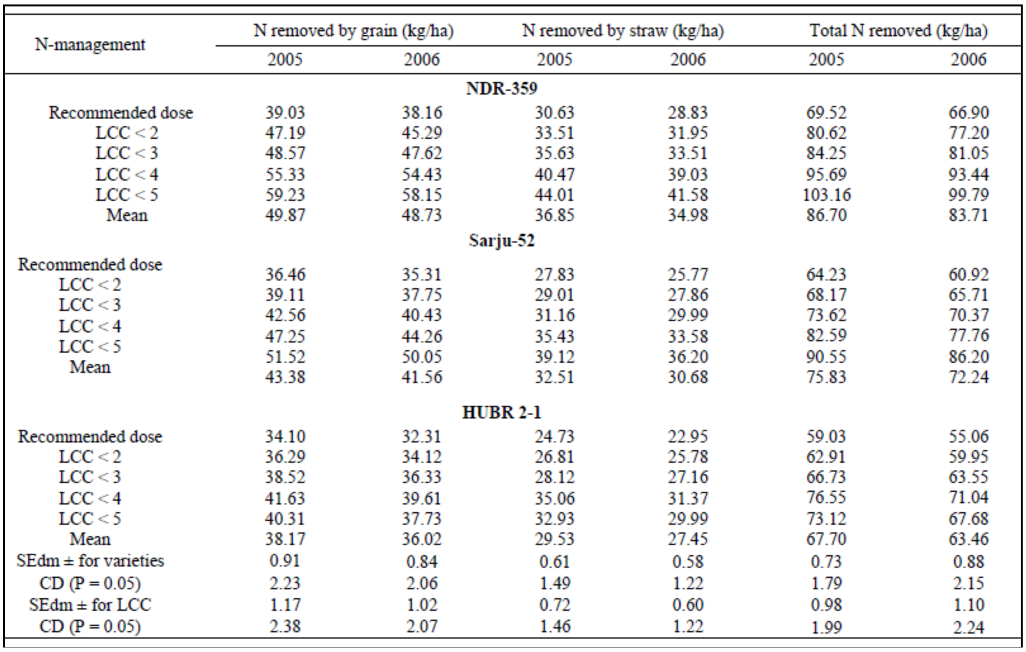


N-management	Filled spikelets/panicle		Unfilled spikelets/panicle		Grain yield (q/ha)		Straw yield (q/ha)		Harvest index (%)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
NDR-359										
Recommended dose	128.11	123.26	32.63	27.70	38.03	36.00	57.11	54.99	39.97	39.47
LCC ≤ 2	136.43	131.58	24.66	19.72	40.02	37.13	58.09	55.93	40.79	39.90
LCC ≤ 3	142.32	137.58	21.62	16.57	41.98	39.39	59.22	57.18	41.48	40.79
LCC ≤ 4	145.61	140.05	20.32	15.46	46.12	43.99	64.31	62.19	41.76	41.43
LCC ≤ 5	146.01	140.64	18.63	13.70	48.33	45.87	65.35	63.31	42.51	42.01
Mean	139.70	134.65	23.57	18.63	42.90	40.47	60.82	58.72	41.30	39.47
Sarju-52										
Recommended dose	128.11	123.77	29.15	24.22	32.31	29.42	50.31	47.28	39.11	37.56
LCC ≤ 2	137.62	132.74	27.63	22.72	34.03	31.17	51.18	50.38	39.94	38.52
LCC ≤ 3	138.63	133.77	27.32	22.49	37.41	34.60	54.97	52.92	40.50	39.20
LCC ≤ 4	139.85	134.92	26.32	21.35	40.29	37.42	58.19	56.21	40.91	39.93
LCC ≤ 5	145.21	140.47	24.29	19.35	42.49	38.82	59.92	57.81	41.49	40.15
Mean	137.88	133.05	26.94	22.02	37.31	34.29	54.91	52.92	40.39	39.07
HUBR 2-1										
Recommended dose	102.39	97.75	45.19	40.50	28.29	25.38	46.21	44.18	37.97	30.47
LCC ≤ 2	113.49	108.62	36.11	31.04	31.33	28.48	49.25	47.28	38.88	36.55
LCC ≤ 3	122.09	117.17	36.97	31.02	33.01	30.08	50.72	48.88	39.42	37.305
LCC ≤ 4	125.37	120.00	29.17	24.25	37.29	34.78	55.32	53.58	40.27	38.68
LCC ≤ 5	123.61	118.55	30.39	25.48	35.51	32.43	53.17	51.23	40.04	37.56
Mean	117.39	112.41	35.41	30.45	33.09	30.23	50.93	49.03	39.32	36.06
SEdm ± for variety	4.01	3.82	2.01	2.11	0.67	0.55	0.71	0.60	0.35	0.26
CD (P = 0.05)	9.81	9.35	4.92	3.15	1.64	1.34	1.74	1.48	0.86	0.64
SEdm ± for LCC	3.41	3.33	1.63	1.78	0.58	0.45	0.56	0.49	0.28	0.22
CD (P = 0.05)	6.93	6.75	3.31	3.61	1.18	0.89	1.14	0.98	0.57	0.46

Source: Avijit Sen *et al.* (2011) Agricultural Research Farm of the Institute at Varanasi.

Avijit Sen *et al.* (2011) also found that the number of panicles m^{-1}, panicle length, panicle weight, filled spikelet's panicle^{-1}, grain filling percentage, test weight, grain and straw yields were found to be higher with NDR 359 among the varieties and with LCC ≤ 5 among the LCC scores except in HUBR 2-1 where LCC ≤ 4 out yielded LCC ≤ 5 (Table 11). Overall, application of N through LCC could register 15.99 and 15.54% for NDR 359, 19.33 and 20.68% for Sarju 52, 21.19 and 23.89% for HUBR 2-1 higher grain yield than recommended dose and split application of N in 2005 and 2006 respectively. LCC strategy calibrated with SPAD determines the real time for efficient management of N (Yang *et al.*, 2003). However, for this critical LCC values are to be determined which may not be same for all the varieties. In the nitrogen removal studies it was observed that maximum amount of N was removed by NDR 359 which was significantly superior to other two varieties during both the years (Table 12). Among the LCC scores while N removal from soil was highest at ≤ 5 for both NDR 359 and Sarju 52, it was highest at LCC ≤ 4 for HUBR 2-1. Further for agronomic and recovery efficiency of N it was found to be highest at LCC ≤ 5 for NDR 359 and Sarju 52 but at LCC ≤ 4 for HUBR 2-1 (Table 13). Nutrient removal is a function of climate, soil properties, amount and method of fertilizer application and the variety of rice De Datta, (1981) [4] where cultural practices and morphological variations account for differences in nutrient removal. In addition to this dry matter production and yield also govern the nu-trient removal. Quite expectedly higher yield by NDR 359 led to higher N removal which was followed by Sarju 52 and HUBR 2-1 respectively. Similarly under LCC score also total N removal was found in the se-quence of 5 > 4 > 3 > 2 > for NDR 359 and Sarju 52, while it was 4 > 5 > 3 > 2 > for HUBR 2-1. In all the cases lowest removal of nitrogen was recorded under the recommended dose and split of N application. This trend clearly suggested that the loss of N was maximum under recommended dose of N application.

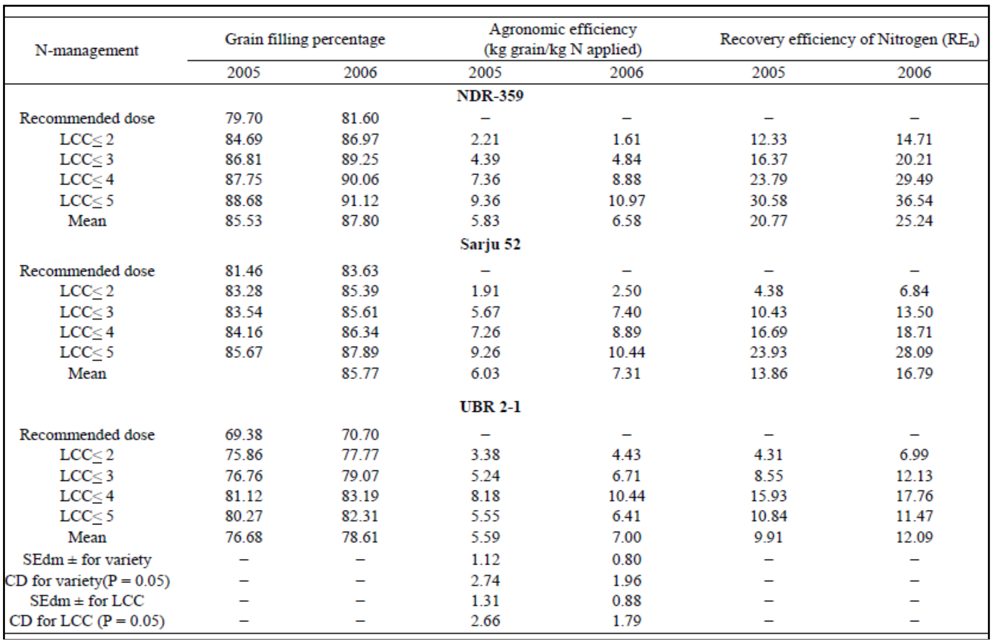
Table 12: Effect of treatments on removal of nitrogen of rice.



N-management	N removed by grain (kg/ha)		N removed by straw (kg/ha)		Total N removed (kg/ha)	
	2005	2006	2005	2006	2005	2006
NDR-359						
Recommended dose	39.03	38.16	30.63	28.83	69.52	66.90
LCC < 2	47.19	45.29	33.51	31.95	80.62	77.20
LCC < 3	48.57	47.62	35.63	33.51	84.25	81.05
LCC < 4	55.33	54.43	40.47	39.03	95.69	93.44
LCC < 5	59.23	58.15	44.01	41.58	103.16	99.79
Mean	49.87	48.73	36.85	34.98	86.70	83.71
Sarju-52						
Recommended dose	36.46	35.31	27.83	25.77	64.23	60.92
LCC < 2	39.11	37.75	29.01	27.86	68.17	65.71
LCC < 3	42.56	40.43	31.16	29.99	73.62	70.37
LCC < 4	47.25	44.26	35.43	33.58	82.59	77.76
LCC < 5	51.52	50.05	39.12	36.20	90.55	86.20
Mean	43.38	41.56	32.51	30.68	75.83	72.24
HUBR 2-1						
Recommended dose	34.10	32.31	24.73	22.95	59.03	55.06
LCC < 2	36.29	34.12	26.81	25.78	62.91	59.95
LCC < 3	38.52	36.33	28.12	27.16	66.73	63.55
LCC < 4	41.63	39.61	35.06	31.37	76.55	71.04
LCC < 5	40.31	37.73	32.93	29.99	73.12	67.68
Mean	38.17	36.02	29.53	27.45	67.70	63.46
SEdm ± for varieties	0.91	0.84	0.61	0.58	0.73	0.88
CD (P = 0.05)	2.23	2.06	1.49	1.22	1.79	2.15
SEdm ± for LCC	1.17	1.02	0.72	0.60	0.98	1.10
CD (P = 0.05)	2.38	2.07	1.46	1.22	1.99	2.24

Source: Avijit Sen *et al.* (2011) Agricultural Research Farm of the Institute at Varanasi.

Table 13: Effect of treatments on grain filling percentage, agronomic and recovery efficiency of rice.



N-management	Grain filling percentage		Agronomic efficiency (kg grain/kg N applied)		Recovery efficiency of Nitrogen (RE_n)	
	2005	2006	2005	2006	2005	2006
NDR-359						
Recommended dose	79.70	81.60	–	–	–	–
LCC≤ 2	84.69	86.97	2.21	1.61	12.33	14.71
LCC≤ 3	86.81	89.25	4.39	4.84	16.37	20.21
LCC≤ 4	87.75	90.06	7.36	8.88	23.79	29.49
LCC≤ 5	88.68	91.12	9.36	10.97	30.58	36.54
Mean	85.53	87.80	5.83	6.58	20.77	25.24
Sarju 52						
Recommended dose	81.46	83.63	–	–	–	–
LCC≤ 2	83.28	85.39	1.91	2.50	4.38	6.84
LCC≤ 3	83.54	85.61	5.67	7.40	10.43	13.50
LCC≤ 4	84.16	86.34	7.26	8.89	16.69	18.71
LCC≤ 5	85.67	87.89	9.26	10.44	23.93	28.09
Mean		85.77	6.03	7.31	13.86	16.79
UBR 2-1						
Recommended dose	69.38	70.70	–	–	–	–
LCC≤ 2	75.86	77.77	3.38	4.43	4.31	6.99
LCC≤ 3	76.76	79.07	5.24	6.71	8.55	12.13
LCC≤ 4	81.12	83.19	8.18	10.44	15.93	17.76
LCC≤ 5	80.27	82.31	5.55	6.41	10.84	11.47
Mean	76.68	78.61	5.59	7.00	9.91	12.09
SEdm ± for variety	–	–	1.12	0.80	–	–
CD for variety(P = 0.05)	–	–	2.74	1.96	–	–
SEdm ± for LCC	–	–	1.31	0.88	–	–
CD for LCC (P = 0.05)	–	–	2.66	1.79	–	–

Source: Avijit Sen *et al.* (2011) Agricultural Research Farm of the Institute at Varanasi.

Conclusion

It may be concluded that when rice leaves will show >35 SPAD value, it has higher amount of chlorophyll as well as nitrogen. However, farmers should use N fertilizer as per leaf colour chart in rice-wheat cropping system, save the excess cost of N fertilizer and get higher net profit. Farmer determine the right time of N application to rice-wheat by measuring leaf colour intensity with leaf colour chart.

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