

Effect of Crop Need Based Nitrogen Management Through Leaf Color Chart (LCC) on Yield, Lodging and Economics of Direct Seeded Rainfed Lowland Rice (*Oryza sativa* L.)

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Abstract An experiment was conducted to optimize nitrogen fertilizer application for drill sown rainfed rice genotype Intan with the help of leaf color chart practice under agro-climatic conditions of Agriculture Research Station, Mugad, Dharwad, Karnataka. The experiment was designed in factorial RCBD consisting of organics as the I factor and N management with LCC as the II factor and farmers practice was kept as a check. The N management at LCC 3 with sunhemp green manuring registered higher grain yield, NUE, B : C ratio and lower lodging index compared to all other treatment combinations, recommended practice and farmers' practice. The adequate supply of N fertilizer in combination with different organic sources according to LCC management practice resulted in positive response of N fertilizer on the growth, yield and NUE of the crop and thus provides the best fertilizer management techniques for enhancing the production and productivity of the crop on sustainable basis.

Keywords LCC, Green manuring, INM, Yield, NUE.

Introduction

Rice is the most important food crop of the developing world and serves as a staple food of almost 3 billion people, that is, about 50% of the World's population and for more than 60% of the Indian population. In India it occupies about 24% of gross cropped area of the country. It contributes 42% of total food grain production and 45% of total cereal production of the country [1] more than any other crop. Thus, the rice systems belong to the most important food production systems on Earth. Among the rice growing countries, India has the largest area (44 million hectares) and it is the second largest producer (105.3 million tonnes) of rice next to China (197 million tonnes) [2]. More than 90% of this is produced and consumed in Asia with two countries, China and India, growing more than half the total crop, providing 50% of the total calorie intake of Asia's population. The rice productivity in India is 2.39 t ha⁻¹, in China 6.58 t ha⁻¹ and while the world average is 4.25 t ha⁻¹ [2]. Most of the rice in tropical countries is produced in irrigated and rainfed lowland areas. Rainfed rice in India constitutes up to 55% of the total rice area and to 36.5% of the country's rice production [1]. Thus low lands become the most important rainfed rice ecosystem in the productivity context. Very low productivity levels of rainfed lowland rice (2.4 t ha⁻¹) are also responsible for the lower average productivity of rice in India compared to the average productivity of the World. Apart from vagaries of monsoon, inadequate and improper nutrient management are the main rea-

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Table 1. Treatments details : The experiment was laid out in a randomized block design with factorial concept and was replicated four times with 13 treatment combinations and treatment details are as follows (Table 1).

Treatment details	
I	Factor : Organics (M)
M ₁	: Farm Yard Manure (FYM) @ 10 t ha ⁻¹
M ₂	: <i>In-situ</i> green manuring with Sunhemp (<i>Crotalaria juncea</i>) @ 10 kg seeds ha ⁻¹ by seed mixing method
M ₃	: Green leaf manuring with Eupatorium (<i>Eupatorium odorata</i>) @ 5 t ha ⁻¹
M ₄	: No organics
II	Factor : Nitrogen management (F)
F ₁	: Nitrogen application at LCC threshold value of 3
F ₂	: Nitrogen application at LCC threshold value of 4
F ₃	: Recommended practice (100 kg N ha ⁻¹ –20% N and entire 50 kg P and 50 kg K were applied at sowing and 40% each at maximum tillering and just before panicle initiation stage)
F ₄	: Farmers' practice (FYM 5 t ha ⁻¹ + 100 : 50 kg N and P ₂ O ₅ ha ⁻¹ –20% N and entire P at sowing and 80% N at panicle initiation stage)

sons for lower yields of drilled rice. The higher nutrient losses caused by leaching, volatilization, run off and denitrification further aggravate the problem of nutrient management in rice. Under rainfed rice cultivation, use of chemical fertilizers is less than 50% of the recommended dose due to limited economic resources of the farmers. Therefore in order to sustain the productivity of rainfed rice at higher level, there is a need to develop a crop need based nitrogen management involving cheaper and locally available organic manures and an inexpensive tools like LCC that can be used to measure green color intensity of rice leaves and thus improves the timing of N top dressing in rice. Identification of correct threshold values of the LCC is essential as they differ according to location, season, variety and rice ecosystem. The experiment was conducted with the main objectives to compare farmers and standard nitrogen fertilizer use practices along with the LCC based method to increase nitrogen use efficiency, yield and to observe the effect of LCC use on minimizing lodging incidence.

Materials and Methods

Experimental site and initial soil characteristics

Field experiment was conducted at rainfed low lands, Agricultural Research Station, Mugad, UAS, Dharwad

during *khari* season to standardise the leaf color chart threshold value for the most promising variety of the region i.e., Intan (165 days) and to find out the contribution of N by different organic sources. The farm is situated in Northern transitional tract (Zone 8) of Karnataka representing the rainfed drill sown rice belt at 25°18' N latitude, 74°40' E longitude and at an altitude of 697 m above mean sea level.

The soil of the experimental site was clay textured (43.3% clay, 24.3% silt and 32.0% sand). The initial analysis of the soil of the experimental site revealed that soil was neutral (pH–7.20) and organic carbon was 0.44%. The soil was high in KMnO₄-N (465 kg ha⁻¹) and NH₄OA_c-K (500 kg ha⁻¹) and low in Olsen-P (31 kg ha⁻¹).

Layout of the field experiment

The field was divided into 52 plots of 16 m² size with adequate drainage channels with clear demarcation of boundary for the four replications. The treatments were allotted to plots using Fisher's random numbers in each replication.

Experimental design, sowing and fertilizer schedule

The study was conducted in factorial randomized block design (FRBD) with four replications. The treat-

Table 2. Amount of nitrogen applied in different treatments.

Treatments	N (kg ha ⁻¹)
M ₁ F ₁	110 (Four splits viz., 5 th , 11 th , 12 th & 13 th week)
M ₁ F ₂	200 (Eight splits viz., 3 rd , 4 th , 6 th , 7 th , 8 th , 11 th , 12 th & 13 th week)
M ₁ F ₃	100 (Two splits viz., 5 th & 13 th week)
M ₂ F ₁	60 (Two splits viz., 12 th & 13 th week)
M ₂ F ₂	180 (Seven splits viz., 4 th , 5 th , 8 th , 9 th , 10 th , 11 th & 13 th week)
M ₂ F ₃	100 (Two splits viz., 5 th & 13 th week)
M ₃ F ₁	80 (Three splits viz., 4 th , 5 th & 13 th week)
M ₃ F ₂	200 (Eight splits viz., 4 th , 5 th , 8 th , 9 th , 10 th , 11 th , 12 th & 13 th week)
M ₃ F ₃	100 (Two splits viz., 5 th & 13 th week)
M ₄ F ₁	100 (Three splits viz., 4 th , 5 th & 11 th week)
M ₄ F ₂	250 (Ten splits viz., 3 rd , 4 th , 5 th , 6 th , 8 th , 9 th , 10 th , 11 th , 12 th & 13 th week)
M ₄ F ₃	100 (Two splits viz., 5 th & 13 th week)
Farmers' practice (Control)	100 (One split viz., 13 th week)

ments (Table 1) included three different sources of organics and one no organic treatment with different 2 levels of LCC (LCC cv 3 and 4) and recommended practice and farmers, practice of the region as check. Furrows were opened at 20 cm row spacing with the help of market and seeds were sown @ 100 kg ha⁻¹. In the entire treatments 20% N (basal) and entire P were applied basally at sowing in the form of Di-ammonium phosphate. Whereas K was applied basally at sowing in the form muriate of potash in all the treatments except farmers' practice.

In case of *in-situ* green manuring with sunhemp treatment sunhemp seeds @ 10 kg ha⁻¹ were mixed with seeds of rice and were sown in all the rows. Sunhemp plants were carefully uprooted at 35-50 days after rice emergence (DARE) and were spread uniformly on the entire plot and incorporated into the soil by passing plank when sufficient rain water accumulated in the field.

In case green leaf manuring with eupatorium, eupatorium was collected in and around the station and was applied @ 5 t ha⁻¹ between 35–40 days after rice emergence (DARE). Eupatorium plants were cut into small pieces and buried in soil in between rows by passing plank when sufficient rain water accumulated in the field.

Layout of the field experiment

The field was divided into 52 plots of 16 m² size with

adequate drainage channels with clear demarcation of boundary for the four replications. The treatments were allotted to plots using Fisher's random numbers in each replication.

Application of organic manures and fertilizers

There are three treatments involving various sources of organic manures such as farm yard manure (FYM), *in-situ* green manuring with sunhemp and green leaf manuring with eupatorium applied on equal N basis. These manures were analyzed for N, P and K contents and the quantity of organic manures were calculated and applied as per the treatments. For the management of weeds three hand weeding was done at 20, 40 and 80 days after rice emergence (DARE).

Leaf color chart (LCC) measurement

Monitoring of plant nitrogen status is important in improving the balance between crop N demand and N supply from soil and applied fertilizer [3]. As leaf N content is closely related to photosynthetic rate [4] and biomass production it is a sensitive indicator of the dynamic changes in crop N demand within a short season. The direct measurement of leaf N concentration by laboratory procedure is laborious, time consuming and costly. Such procedures have limited use as a diagnostic tool for optimizing N topdressing be-

Table 3. Growth and yield parameters of rainfed lowland rice as influenced by organic sources and LCC based N management at harvest. F^* -test at 5% refers to Factor I and Factor II without check, F^{**} -test at 5% refers to interaction effect of treatments with check.

Treatments	Leaf area per m length (cm ²)		Leaf area index		Dry matter production (gm plant ⁻¹)	No. of grains per panicle		Per cent chaff		
Factor I : Organics (M)										
M ₁ : Farm Yard Manure (FYM) @ 10 t ha ⁻¹	2488.5	a	0.93	a	33.53		111.4		19.5	
M ₂ : Sunhemp @ 10 kg seeds ha ⁻¹	2533.0	a	0.96	a	34.38		120.0		19.0	
M ₃ : Eupatorium @ 5 t ha ⁻¹	2550.1	a	0.92	ab	33.43		115.2		21.4	
M ₄ : No organics	1977.0	b	0.78	b	33.20		104.1		21.1	
Farmers' practice (FP)	1672.2	b	0.61	c	31.78		110.0		19.0	
F^* -test	S		NS		NS		NS		NS	
II Factor : Nitrogen management (F)										
F ₁ : LCC 3	2871.8	a	1.13	a	38.14	a	132.7	a	17.1	c
F ₂ : LCC 4	2210.3	b	0.76	b	29.35	c	101.8	b	22.9	a
F ₃ : Recommended practice (RP)	2179.0	b	0.80	b	32.64	b	103.5	b	20.8	b
Farmers' practice (FP)	1672.2	c	0.61	c	31.78	bc	110.0	b	19.0	bc
F^* - test	S		S		S		S		S	
Treatment combinations (M×F) and C										
M ₁ F ₁	3118.0	a	1.22	a	38.88	ab	127.1	a-c	16.7	d
M ₁ F ₂	2212.6	bc	0.86	bc	30.44	de	107.8	cd	19.8	cd
M ₁ F ₃	2314.8	bc	0.71	b-d	31.36	c-e	99.3	cd	22.1	bc
M ₂ F ₁	3149.5	a	1.23	a	42.82	a	144.4	a	16.3	d
M ₂ F ₂	2296.7	bc	0.88	bc	27.61	e	111.8	cd	18.3	cd
M ₂ F ₃	2152.8	bc	0.76	b-d	32.59	b-e	103.7	cd	22.2	bc
M ₃ F ₁	3158.4	a	1.27	a	37.55	a-c	140.7	ab	17.0	d
M ₃ F ₂	1930.3	bc	0.58	d	27.56	e	92.0	d	28.7	a
M ₃ F ₃	2561.6	ab	0.90	b	35.20	b-d	113.0	b-d	18.5	cd
M ₄ F ₁	2061.5	bc	0.81	b-d	33.41	b-e	118.6	a-d	18.3	cd
M ₄ F ₂	2002.7	bc	0.70	b-d	31.79	c-e	95.5	d	24.9	ab
M ₄ F ₃	1866.8	bc	0.83	b-d	31.40	c-e	98.2	cd	20.2	cd
Farmers' practice (Control)	1672.2	c	0.61	cd	31.78	c-e	110.0	cd	19.0	cd
F^{**} -test (MXF) and C		S		S		S		S		

cause of the extensive time delay between sampling and obtaining results [5]. The leaf color chart (LCC) is an easy-to-use and inexpensive diagnostic tool for monitoring the relative greenness of a rice leaf as an indicator of the plant N status. Inexpensive leaf color chart (LCC) has proved quick and reliable tool to decide the time of when fertilizer needs to be applied to the crop. The use of LCC will really help the farmers in deciding the right time N fertilization thereby increas-

ing the productivity and profitability of direct seeded rice and reduction in loss of nitrogen fertilizer.

The LCC was developed from a Japanese prototype by the Crop and Resource Management Network (CREMNET) at IRRI and the Philippine Rice Research Institute, Philippines (Phil Rice) for the purpose of measuring the required quantity of nitrogen to be applied in the rice fields.

Table 4. Yield, harvest index, nitrogen use efficiency (NUE), agronomic efficiency and B : C ratio rainfed lowland rice as influenced by organic sources and LCC based N management at harvest. F^* -test at 5% refers to Factor I and Factor II without check, F^{**} -test at 5% refers to interaction effect of treatments with check.

Treatments	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Harvest index (%)	NUE (%)	B:C ratio					
Factor I : Organics (M)										
M ₁ : Farm Yard Manure (FYM) @ 10 t ha ⁻¹	3.30	6.23	ab	34.8	ab	27.1	c	0.61	c	
M ₂ : Sunhemp @ 10 kg seeds ha ⁻¹	3.22	6.02	b	35.1	ab	36.1	a	1.04	a	
M ₃ : Eupatorium @ 5 t ha ⁻¹	3.15	7.05	a	31.5	bc	31.1	b	0.98	a	
M ₄ : No organics	3.05	7.10	a	30.2	c	25.5	c	1.02	a	
Farmers' practice (FP)	3.22	5.56	c	37.2	a	32.2	b	0.84	b	
F^* -test	NS	S	S	S	S	S	S	S	S	
F ₁ : LCC 3	3.62	a	6.21	ab	37.3	a	44.4	a	1.16	a
F ₂ : LCC 4	2.68	c	7.01	a	28.3	c	13.3	c	0.62	d
F ₃ : Recommended practice (RP)	3.21	b	6.57	a	33.0	b	32.2	b	0.96	b
Farmers' practice (FP)	3.22	b	5.56	b	37.2	a	32.2	b	0.81	c
F^* - test	S	NS	S	S	S	S	S	S	S	
M ₁ F ₁	3.64	a-c	5.56	c	39.8	ab	33.1	c	0.71	c-e
M ₁ F ₂	2.86	d-f	6.25	bc	31.5	c-e	14.3	ef	0.40	f
M ₁ F ₃	3.38	a-d	6.87	bc	33.2	b-e	33.9	c	0.73	c-e
M ₂ F ₁	3.86	a	5.56	c	40.9	a	64.3	a	1.41	a
M ₂ F ₂	3.14	c-f	5.97	bc	35.3	a-d	17.3	e	0.89	c
M ₂ F ₃	2.65	e-g	6.53	bc	29.0	de	26.5	d	0.82	cd
M ₃ F ₁	3.81	ab	6.33	bc	37.6	a-c	47.6	b	1.30	ab
M ₃ F ₂	2.14	g	8.78	a	19.7	f	10.7	f	0.55	ef
M ₃ F ₃	3.51	a-c	6.03	bc	37.2	a-c	35.1	c	1.10	b
M ₄ F ₁	3.26	a-d	7.42	ab	30.9	c-e	32.6	c	1.22	b
M ₄ F ₂	2.58	fg	7.03	bc	26.9	e	10.9	f	0.64	de
M ₄ F ₃	3.30	a-d	6.86	bc	32.7	b-e	33.0	c	1.20	b
Farmers' practice (Control)	3.22	b-e	5.56	c	37.2	a-c	32.2	c	0.81	cd
F^{**} -test (MXF) and C	S	S	S	S	S	S	S	S	S	

The leaf color chart (LCC) is an innovative cost effective tool for real-time or crop-need-based N management in Rice. LCC is a visual and subjective indicator of plant nitrogen deficiency and is an inexpensive, easy to use and simple alternative to chlorophyll meter / SPAD meter (soil plant analysis development). It measures leaf color intensity that is related to leaf N status. LCC is an ideal tool to optimize N use in rice irrespective of the source of N applied, viz., organic manures, green manures biologically fixed N, or chemical fertilizers. Thus, it is an eco-friendly tool in the hands of farmers.

LCC is made of high quality plastic material [6, 7].

It consists of six green color shades ranging from light yellowish green (No. 1) to dark green (No. 6). The color strips are fabricated with veins resembling those of rice leaves.

LCC readings were taken at weekly intervals from 21 DARE until the first flower appeared. Youngest fully expanded leaf of a plant was selected at random for each plot. The color of the index leaf (fully opened third leaf from top upto panicle emergence and boot leaf after panicle emergence) of selected plants was compared with the color strips of the chart. Leaf color was observed by keeping the sun blocked by body

Table 5. Effect of crop seed based N management on lodging of rice plants at grain filling stage.

Treatments combinations (M × F) and C	Score for no. of plants lodged	Score for extent of plants lodged	Lodging index (No. × Extent)
M ₁ F ₁	6.38	7.75	49.4
M ₁ F ₂	8.50	8.00	38.0
M ₁ F ₃	7.75	7.00	54.3
M ₂ F ₁	6.88	6.50	44.7
M ₂ F ₂	8.50	7.50	63.8
M ₂ F ₃	7.50	6.63	49.7
M ₃ F ₁	7.01	6.33	44.4
M ₃ F ₂	8.63	9.00	77.7
M ₃ F ₃	7.17	6.33	45.4
M ₄ F ₁	8.13	7.63	62.0
M ₄ F ₂	9.00	9.17	82.5
M ₄ F ₃	8.50	6.50	55.3
Farmers' practice (Control)	6.25	6.00	37.5

as sun light affects leaf color reading in morning time. Average of 20 LCC readings of four replications were calculated and when the average leaf color reading fall below the set critical value the N fertilizer was top dressed immediately to correct the N deficiency. The amount of N fertilizer applied at different growth stages is given in Table 2.

Biometrical observations : Five plants were selected at random at each stage for recording biometric observations.

Leaf area per meter length :

$$\text{Leaf area per meter length} = \frac{\text{Leaf area per tiller} \times \text{Total number of tillers per meter length}}{\text{meter length}}$$

The average leaf area at five places in net plot was worked out

Number of grains per panicle : All the spikelets were removed from the panicles and numbers of filled grains were counted for five different panicles and their mean was taken as number of filled grains per panicle.

Per cent chaff : The chaff grains per panicle and total

number of grains (spikelets) per panicle were counted and per cent chaff was worked out with the formula:

$$\text{Percent chaff} = \frac{\text{Number of chaffy seeds per panicle}}{\text{Total number of seeds per panicle}} \times 100$$

Grain and straw yield : Grain and straw yields were recorded separately for each net plot area and expressed at 14% moisture level using the formula of Yoshida et al. [8].

Harvest index : The harvest index was worked out using grain and straw yields with the help of formula given by Donald [9].

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Grain+Straw yield}} \times 100$$

Lodging index : Lodging index was worked out using the formula:

$$\text{Lodging index} = \frac{\text{Score for no. of plants lodged (N)} \times \text{Score for extent of lodging (E)}}{\text{Score : 0—10}}$$

Where 0 = no lodging

10 = 100% of plants lodged / lodged plants completely touching the ground.

Statistical analysis : The data collected from the experiment was subjected to statistical analysis as described by Gomez and Gomez [10]. The mean values were separately subjected to Duncan's Multiple Range Test (DMRT) at 5% probability under MSTAT-C program.

Results and Discussion

Effect on growth attributes

Leaf area and LAI

Significant differences were observed in leaf area per meter row length and LAI among different organic sources. Sunhemp green manuring recorded the highest leaf area per meter row length and LAI (2533.0 cm²

and 0.96) respectively whereas the farmers, practice recorded the lowest value (1672.2 cm² and 0.61) (Table 3). In case of N management, N management at LCC 3 (2871.8 cm² and 1.13) recorded the higher leaf area per meter row length and LAI respectively than compared to other N management practices. Variation due to the effect of treatment combinations was significant. Significantly higher leaf area per meter row length and LAI were observed with M₃F₁ i.e., eupatorium green manuring at LCC threshold value of 3 nitrogen management (3158.4 cm² and 1.27), M₂F₁ i.e., *in-situ* green manuring with sunhemp at LCC threshold value of 3 nitrogen management (3149.5 cm² and 1.23) and M₁F₁ i.e., application of FYM at LCC threshold value of 3 nitrogen management (3118.0 cm² and 1.22) respectively [11, 12].

Effect on yield and yield attributes

Organics did not differ significantly with respect to yield and yield attributes like filled grains per panicle, per cent chaff and grain yield. In spite of favorable effect of organics on growth components, the advantage was not noticed on grain yield. This might be due to lack of response of organics alone on yield components like filled grains per panicle. This indicates that effect of organics can be noticed only by continuous use of organics in fixed site, which is likely to create fertility gradient compared to the plots without organics and is expected to give enhanced productivity [13, 14].

Nitrogen management at LCC 3 recorded significantly higher filled grains per panicle (132.7) and lower per cent chaff (17.1%) than N management at LCC 4, recommended practice and farmers' practice (Table 3) and thus resulted in higher grain yield. The increase in grain yield was to the extent of 26.4, 11.8 and 11.9% than N management at LCC 4, recommended practice and farmers' practice respectively (Table 4). This may be attributed to increased yield attributes like filled grains per panicle and lower per cent chaff and growth parameters like leaf area and dry matter production. These results are in conformity with the findings of recommendation of [6, 15—17]. While the straw

yield was significantly higher at LCC 4 which could be attributed to their favorable influence on vegetative growth rather than on grain yield. However, it was on par with N-management at LCC 3. The same treatment recorded the highest harvest index (37.3%) than others.

Among the treatment combinations, green manuring with sunhemp at LCC 3 i.e. M₂F₁ gave significantly higher grain yield than other combinations and check (17 and 20%) increase over 100% recommended practice without organics and farmers, practice respectively. The harvest index (40.6%) was also recorded significantly higher in the same treatment.

Straw yield was higher with eupatorium green leaf manuring (7.05 t ha⁻¹) followed by no organic treatment (7.01 t ha⁻¹) and FYM application (6.23 t ha⁻¹) than sunhemp green manuring and check (6.02 and 5.56 t ha⁻¹) respectively. This could be due to the restricted growth of rice till incorporation of sunhemp [18, 19]. Among the treatment combinations, straw yield was significantly higher in M₃F₁ i.e., eupatorium green leaf manuring at LCC threshold value of 3 (8.78 t ha⁻¹) and lower straw yield was observed in M₁F₁, M₂F₁ and Check (5.56 t ha⁻¹).

Benefit cost ratio (B:C ratio)

The ultimate aim of any agricultural practice is to obtain maximum return per rupee invested. This also gives a clear idea about the optimum level of input that could be recommended to obtain the maximum profit. Green manuring with sunhemp and eupatorium and no organic treatment recorded higher B:C ratio than FYM application and check. Among the N management treatments, N management at LCC 3 recorded significantly higher B:C ratio (1.16) than others. Whereas, N management at LCC 4 recorded significantly lower B:C ratio (0.62) than all other treatments.

Green manuring with sunhemp at LCC 3 i.e. M₂F₁ gave highest B:C ratio (1.41) than almost all other treatment combinations and check. This might be due

to lower cost of cultivation and number of splits of N application. The lowest B:C ratio (0.40) was with M_1F_1 . Higher net returns with conjunctive use of green manures and inorganic N have also been reported earlier [20–22].

Lodging index

The number of plants lodged, extent of lodging and lodging index was more in treatment with N management at LCC 4 compared to that at LCC 3 and recommended practice. In presence of organics, N management at LCC 3 recorded lower lodging than the recommended practice. M_4F_2 recorded highest lodging index (Table 5). This resulted in lower grain yield (2.58 t ha^{-1}) N management at higher LCC values with higher quality of N application resulted in excessive vegetative growth and lodging and in turn reduced yield. This could be due to increased N content which makes the plant succulent and thus leads to lodging [23].

Conclusion

From the above findings it is clear that for rainfed drill sown Intan rice the LCC critical value of 3 is most appropriate dose of N. Integration of locally available organics i.e. green manures and inorganics fertilizers and use of leaf color chart increases the nitrogen use efficiency and helps in saving 20–40% of inorganic fertilizers. Thus, this practice helps in enhancing the productivity and profits compared to inorganic fertilizers and farmers, practice.

References

- Anonymous (2011) Vision 2030. Central Rice Research Institute, Indian Council of Agricultural Research Cuttack (Odisha) 753006 India. http://www.crii.nic.in/crri_vision2030_2011.pdf
- Anonymous (2014) Status paper on rice. Directorate of Rice Development, Govt. of India 250A, Patliputra Colony, Patna (Bihar). <http://www.nfsm.gov.in/Publicity/2014-15/>
- Cassman KG, Dobermann A, Walters DT (2002) Agroecosystems, nitrogen use efficiency and nitrogen management. *Ambio* 31 : 132–140.
- Peng S, Buresh RJ, Huang J, Zhong X, Zou Y, Yang J, Guanghuo Wang G, Liu Y, Hu R, Tang Q, Cui K, Zhang F, Dobermann A (2010) Improving nitrogen fertilization in rice by site-specific N management—A review. *Agron Sustain Dev* 30 (2010) 649–665.
- Yang WH, Peng S, Huang J, Sanico AL, Buresh RJ, Witt C (2003) Using leaf color charts to estimate leaf nitrogen status of rice. *Agron J* 95 : 212–217.
- Gunasekhar Nachimuthu, Velu V, Malarvizhi P, Ramasamy S, Gurusamy L (2007) Standardization of leaf color chart based nitrogen management in direct wet seeded rice (*Oryza sativa* L.). *J Agron* 6 : 338–343.
- Sathiya K, Ramesh T (2009) Effect of split application of nitrogen on growth and yield aerobic rice. *Asian J Exp Sci* 23 : 303–306.
- Yoshida S, Forno DA, Cock JH, Gomez KA (1976) Laboratory manual for physiological studies of rice. 3rd edn. Int Rice Res Institute, Manila, Philippines.
- Donald CM (1962) In search of yield. *J Aust Inst Agric Sci* 28 : 171–178.
- Gomez KA, Gomez AA (1984) Statistical procedure for Agricultural Research. 2nd edn. John Wiley and Son, New York.
- Neelima TL, Bhanu Murthy VB (2010) Growth and yield attributes of rice as influenced by N fertilizer and differential incorporation of sunhemp green manure. *J Rice Res* 2 : 45–50.
- Sen Avijit, Srivastava Vinod Kumar, Singh Manoj Kumar, Singh Ram Kumar, Kumar Suneel (2011) Leaf color chart vis-a-vis nitrogen management in different rice genotypes. *Am J Pl Sci* 2 : 223–236.
- Sarkar MAR, Pramanik MYA, Faruk GM, Ali MY (2004) Effect of green manures and levels of nitrogen on some growth attributes of transplant aman rice. *Pak J Biol Sci* 7 : 739–742.
- Yadana KL, Aung KM, Takeo Y, Kazuo O (2009) The effects of green manure (*Sesbania rostrata*) on the growth and yield of rice. *J Fac Agr Kyushu Univ* 54 : 313–319.
- Krishnakumar S, Haefele S (2013) Integrated nutrient management and LCC based nitrogen management on soil fertility and yield of rice (*Oryza sativa* L.). *Scientific Res and Essays* 8 : 2059–2067.
- Singh H, Sharma KN, Dhillon GS, Amanpreet Singh T, Singh V, Kumar D, Singh B, Singh H (2010) On-farm evaluation of real time nitrogen management in rice. *Better Crop* 94 : 26–28.
- Sen A, Srivastava VK, Singh MK, Singh RK, Kumar S (2011) Leaf color chart vis-a-vis nitrogen management in different rice genotypes. *Am J Pl Sci* 2 : 223–236.
- Jagadeeswari PV, Kumaraswamy K (2000) Long term effects of manure fertilizer schedules on the yields and nutrient uptake by rice crop in a permanent manorial experiment. *J Ind Soc Soil Sci* 48 : 883–886.
- Singh SP, Subbaiah SV, Kumar RM (2000) Nitrogen management under direct seeded rice in puddle conditions. In : Abstracts of the 3rd CREMNET–India workshop cum meeting on direct seeding and seeders in rice. Mysore, 18–19 August, 2000,

- pp 8.
20. Channbasappa KS, Madiwalar SL, Joshi VR, Manjappa K (2005) Effect of sources of green leaf manures on growth, yield and productivity of low land rice. *Karnataka J Agric Sci* 18 : 842—844. doi : 10.3923/pjbs.2004.739.742, <http://dx.doi.org/10.3923/pjbs.2004.739.742>
 21. Surekha K, Jhansilakshmi V, Somasekhar N, Latha PC, Kumar RM, Shobha Rani N, Rao KV, Virakta-math BC (2010) Status of organic farming and research experiences in rice. *J Rice Res* 3 : 23—35.
 22. Baishya LK, Rathore SS, Singh Dharmendra, Sarkar Dibyendu, Deka BC (2015) Effect of integrated nutrient management on rice productivity, profitability and soil fertility. *Ann Pl and Soil Res* 17 : 86—90.
 23. Rajkumara S (2008) Lodging in cereals—A review. *Agric Rev* 29 : 55—60.