

Influence of Integrated Nitrogen Management and Leaf Color Chart (LCC) Based Nitrogen Management on Rice (*Oryza sativa* L.) Yield and Yield Attributes, Nitrogen Uptake and Soil Available Nitrogen Status

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Abstract Rice (*Oryza sativa* L.) is one of the most important staple food crops in the world. Nitrogen is the major nutrient limiting the high yield potential of rice cultivars. Application of over dose of N fertilizers results in lower grain yield due to lodging and high incidence of pests and diseases. So, precise N application based on crop need and farmer friendly tool helps in improving the yield and reduces the N losses. One of the recently introduced nitrogen management approach is estimating the leaf nitrogen concentration by the measurement of leaf greenness. 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. A field experiment was conducted to study the effect of integrated nitrogen management and leaf color chart (LCC) based nitrogen management on rice (*Oryza sativa* L.) yield and yield attributes nitrogen uptake and soil available nitrogen status. The N management at LCC-3 with sunnhemp green manuring registered high grain yield as result of higher available N in the soil and seems enhanced growth and yield attributes followed by green leaf manuring with eupatorium with N management at LCC-3. Thus, the N management at LCC threshold value of 3 was found to be optimum for Intan rice.

Keywords LCC, Green manuring, INM, N uptake, Yield.

Introduction

Rice is the most important staple food crop of Asia and the also the World. In India, it covers about one-fourth of the total cropped area and providing food to about half of the Indian population. Rice is life for thousands of millions of people. Every third person on the earth eats rice everyday in one form or the other and 90% of the total rice produced is consumed in Asian countries. In India, Rice occupies an area of

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Table 1. 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 , and 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 and 13 th week)
M ₁ F ₃	100 (Two splits viz., 5 th and 13 th week)
M ₂ F ₁	60 (Two splits viz., 12 th and 13 th week)
M ₂ F ₂	180 (seven splits viz., 4 th , 5 th , 8 th , 9 th , 10 th , 11 th and 13 th week)
M ₂ F ₃	100 (Two splits viz., 5 th and 13 th week)
M ₃ F ₁	80 (Three splits viz., 4 th , 5 th and 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 and 13 th week)
M ₃ F ₃	100 (Two splits viz., 5 th and 13 th week)
M ₄ F ₁	100 (Three splits viz., 4 th , 5 th and 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 and 13 th week)
M ₄ F ₃	100 (Two splits viz., 5 th and 13 th week)
Farmers' practice (Control)	100 (One split viz., 13 th week)

43.42 Mha, producing 98.95 Mt of grain with an average productivity of 2,279 kg/ha [1]. Though India ranks second position in production of rice, its productivity is very low in comparison to other major rice producing countries in the world. Among various reasons for low productivity, inefficient utilization of nitrogen is considered to be the most critical one.

Nearly 60% of applied nitrogen is lost due to lack of synchronization between the nitrogen demand and nitrogen supply. Increase in fertilizer nutrient input, especially N fertilizer, contributes significantly to the improvement of crop yields in the world [2]. Farmers generally apply nitrogen fertilizer in fixed time blanket recommended N split schedule at basal, maximum tillering and panicle initiation stages respectively, without taking into account whether the plant really requires N at that time or not. The higher nitrogen use efficiency can be achieved by matching N supply with crop demand. In this regard the site specific nitrogen management has the potential to increase fertilizer use efficiency as well as grain yield [3]. Improved Nitrogen management and balanced fertilization are key components of the site-specific nutrient management approach development [4]. The optimum use of N can be achieved by matching N supply with crop

Table 2. Plant height (cm) of rainfed lowland rice as influenced by organic sources and LCC based N management at various growth stages. *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	Maximum tillering	Panicle initiation	Flowering
Factor I: Organics (M)			
M ₁ : Farm yard manure (FYM @ 10 t ha ⁻¹)	37.9	99.0	108.2 a
M ₂ : Sunnhemp @ 10 kg seeds ha ⁻¹	37.1	99.8	110.0 a
M ₃ : Eupatorium @ 5 t ha ⁻¹	38.6	101.0	112.5 a
M ₄ : No organics	37.2	96.2	109.0 a
Farmers' practice (FP)	36.8	97.0	102.8bb
<i>F</i> * - test	NS	NS	NS
II factor : Nitrogen management (F)			
F ₁ : LCC 3	38.6	102.0	113.6 a
F ₂ : LCC 4	37.9	95.9	108.5 b
F ₃ : Recommended practice (RP)	36.5	99.1	107.8 b
Farmers' practice (FP)	36.8	97.0	102.5 c
<i>F</i> * - test	NS	NS	S
Treatment combination (M×F) and C			
M ₁ F ₁	39.2 ab	102.8	111.6
M ₁ F ₂	37.2 ab	95.6	106.9
M ₁ F ₃	37.4 ab	98.6	106.2
M ₂ F ₁	39.3 ab	105.2	115.0
M ₂ F ₂	36.6 ab	97.6	107.7
M ₂ F ₃	35.4 ab	96.8	107.5
M ₃ F ₁	37.5 ab	104.9	114.7
M ₃ F ₂	39.7 a	96.2	110.3
M ₃ F ₃	38.6 ab	102.0	112.6
M ₄ F ₁	38.3 ab	95.3	113.2
M ₄ F ₂	38.4 ab	94.2	109.0
M ₄ F ₃	34.8 a	99.1	104.9
Farmers' practice (Control)	36.8 ab	97.0	102.8
<i>F</i> ** -test (M × F) and C	NS	NS	NS

demand as the leaf color intensity is directly related to leaf chlorophyll content which, in turn, is related to leaf N status. A simple and quick method for estimating plant N demand is LCC i.e. leaf color chart which can estimate leaf chlorophyll content in a non-destructive manner. The LCC, a plant health indicator, has been found to be an ideal tool to optimize the N supply in rice cropping. LCC is easy to use and is an inexpensive accurate diagnostic tool for monitoring the relative greenness of a rice leaf as an indicator for

Table 3. Number of tillers per meter row length of rainfed lowland rice as influenced by organic sources and LCC based N management at various growth stages. *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	Maximum tillering	Panicle initiation	Flowering
Factor I: Organics (M)			
M ₁ : Farm yard manure (FYM) @ 10 t ha ⁻¹	57.0 ab	91.2	83.3 ab
M ₂ : Sunnhemp @ 10 kg seeds ha ⁻¹	57.8 ab	92.9	85.8 a
M ₃ : Eupatorium @ 5 t ha ⁻¹	60.8 a	91.9	82.7 ab
M ₄ : No organics	52.2 b	92.3	80.6 bc
Farmers' practice (FP)	58.2 ab	90.2	78.2 c
<i>F</i> *-test	NS	NS	S
II factor : Nitrogen management (F)			
F ₁ : LCC 3	60.8 a	95.7 a	84.7 ab
F ₂ : LCC 4	56.3 b	88.3 c	81.6 b
F ₃ : Recommended practice (RP)	56.8 b	92.2 b	82.9 ab
Farmers' practice (FP)	58.2 ab	90.2 bc	78.2 c
<i>F</i> *-test	S	S	S
Treatment combination (M×F) and C			
M ₁ F ₁	61.7 a	93.8 a-d	84.3 ab
M ₁ F ₂	52.6 c	90.9 c-e	82.6 ab
M ₁ F ₃	56.9 a-c	88.9 de	83.1 ab
M ₂ F ₁	64.5 a	98.4 a	88.9 a
M ₂ F ₂	57.4 a-c	87.5 ef	83.6 ab
M ₂ F ₃	51.6 c	92.8 a-e	84.8 ab
M ₃ F ₁	63.6 a	97.1 ab	84.9 ab
M ₃ F ₂	58.5 a-c	83.0 f	79.6 b
M ₃ F ₃	60.3 ab	95.7 a-c	83.6 ab
M ₄ F ₁	53.4 bc	93.4 a-d	80.7 b
M ₄ F ₂	57.0 a-c	92.1 b-e	80.7 b
M ₄ F ₃	58.4 a-c	91.6 b-e	80.4 b
Farmers' practice (Control)	58.2 a-c	90.2 c-e	78.2 b
<i>F</i> ** -test (M×F) and C	S	S	NS

the plant N status.

In addition to this, the continuous application of suboptimal doses of chemical fertilizers to soil has resulted in the deterioration of soil health, environmental pollution and stagnation or decrease in crop productivity. Thus, integrated use of organic manures with optimal levels on N fertilizers with the use of LCC is the need of the day that will not only improve the nutrient status and soil health but has greater potential in stabilizing crop yields over a period of time. Keeping these points in view the following field

Table 4. Leaf area (cm²) per plant of rainfed lowland rice as influenced by organic sources and LCC based N management at various growth stages. *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	Maximum tillering	Panicle initiation	Flowering
Factor I: Organics (M)			
M ₁ : Farm yard manure (FYM) @ 10 t ha ⁻¹	149.4	545.3 ab	431.9 a
M ₂ : Sunnhemp @ 10 kg seeds ha ⁻¹	149.0	619.9 a	398.1 ab
M ₃ : Eupatorium @ 5 t ha ⁻¹	149.4	572.8 ab	352.0 bc
M ₄ : No organics	135.0	520.2 b	341.6 bc
Farmers' practice (FP)	148.2	401.3 c	295.6 c
<i>F</i> *-test	NS	NS	S
II factor : Nitrogen management (F)			
F ₁ : LCC 3	162.9 a	648.4 a	440.0 a
F ₂ : LCC 4	135.2 b	527.3 b	356.5 b
F ₃ : Recommended practice (RP)	139.0 b	517.9 b	346.1 bc
Farmers' practice (FP)	148.2 ab	401.3 c	295.6 c
<i>F</i> *-test	S	S	S
Treatment combinations (M×F) and C			
M ₁ F ₁	159.5 ab	583.7 bc	397.7 b
M ₁ F ₂	143.8 ab	527.2 b-d	542.3 a
M ₁ F ₃	145.0 ab	525.0 b-d	355.6 bc
M ₂ F ₁	181.7 a	825.8 a	542.3 a
M ₂ F ₂	141.8 ab	577.5 bc	319.3 cd
M ₂ F ₃	123.5 b	456.6 cd	332.7 cd
M ₃ F ₁	166.6 ab	662.5 b	460.3 ab
M ₃ F ₂	126.5 b	474.5 cd	224.7 d
M ₃ F ₃	153.2 ab	581.3 bc	371.1 bc
M ₄ F ₁	141.8 ab	521.8 b-d	39.8 bc
M ₄ F ₂	128.9 b	530.1 b-d	339.8 b-d
M ₄ F ₃	134.3 ab	508.7 b-d	325.0 cd
Farmers' practice (Control)	148.2 ab	401.3 d	295.6 cd
<i>F</i> ** -test (M×F) and C	S	S	S

experiment was conducted to determine the critical threshold LCC values and contribution of N by various organic sources on growth, yield, N uptake and soil available N status.

Materials and Methods

The experiment was carried out at Agricultural Research Station, Mugad, UAS, Dharwad which is situated between 25°18'N latitude, 74°40' E longitude and at an altitude of 697 m above mean sea level. The

station lies in Northern transitional tract (Zone 8) of Karnataka representing the rainfed drill sown rice belt. The average annual rainfall is 1,013 mm, major part of which is received during the later part of June to mid October. The soil of the experimental site was clayey soil with pH of 7.2 and organic carbon of 0.44%. The soil was medium in N (465 kg ha⁻¹) and P (31 kg ha⁻¹) and high in K (500 kg ha⁻¹).

The variety Intan (165 days) was raised during *kharif* season (June—December). The experimental plot was ploughed and harrowed twice to attain a fine soil tilth condition. The soil surface was compacted by passing the wooden plank. After preparing the field the treatments were imposed as per the plan.

Treatment 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.

I factor : Organics (M)

M₁ : Farm Yard Manure (FYM) @ 10 t ha⁻¹, M₂ : *In-situ* green manuring with sunnhemp (*Crotalaria juncea*) @ 10 kg seeds ha⁻¹ by seed mixing method, M₃ : Green leaf manuring with eupatorium (*Eupatorium odorata*) @ 5 t ha⁻¹, M₄ : No organics.

II factor : Nitrogen management (F)

F₁ : Nitrogen application at LCC threshold value of 3, F₂ : Nitrogen application at LCC threshold value of 4, F₃ : Recommended practice (100 kg N ha⁻¹–20% N and entire 50 kg P and 50 kg K were applied at sowing and 40% N each at maximum tillering and just before panicle initiation stage), F₄ : Farmers' practice (FYM 5 tha⁻¹ + 100: 50 kg N and P₂O₅ ha⁻¹–20% N and entire P at sowing and 80% N at panicle initiation stage). In all the treatments 20% N and entire P were applied basally at sowing in the form of diammonium phosphate. Whereas K was applied basally at sowing in the form muriate of potash in all the treatments except farmers' practice.

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 sunnhemp 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

The LCC developed from a Japanese prototype with six green shades ranging from yellowish green to dark green was used in the trial. LCC readings were taken at 7 days interval starting from 21 DARE until the first flower appeared. Youngest fully expanded leaf of a plant was selected. From each plot, five leaves from five randomly selected plants were selected. LCC readings were taken by placing the middle part of the leaf on the chart and the leaf color was observed by keeping the sun blocked by body as sun light affects leaf color reading. Average of 20 LCC readings of four replications were calculated and when the average leaf color reading fall below the set critical values 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 1.

Biometrical observations

Five plants were selected at random at each stage for recording biometric observations. Plant height was recorded from ground level to the tip of the top most leaf or panicle and the mean height was worked out and expressed in centimeter. Number of tillers was counted at tillering and flowering stages and produc-

Table 5. Yield and yield attributes of rainfed lowland rice as influenced by organic sources and LCC based N management at various growth stages. 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	Panicle weight (gm)		No. of filled grains per panicle		1,000-grain weight (gm)		Grain yield (t ha ⁻¹)		Straw yield (t ha ⁻¹)	
Factor I : Organics (M)										
M ₁ : Farm yard manure (FYM) @ 10 t ha ⁻¹	3.01		111.4		23.9	a	3.30		6.23	ab
M ₂ : Sunnhemp @ 10 kg seeds ha ⁻¹	3.28		120.0		24.1	a	3.22		6.02	b
M ₃ : Eupatorium @ 5 t ha ⁻¹	3.18		115.2		24.6	a	3.15		7.05	a
M ₄ : No organics	3.06		104.1		24.5	a	3.05		7.10	a
Farmers' practice (FP)	2.99		110.0		22.9	b	3.22		5.56	c
F^* - test	NS		NS		NS		NS		S	
II factor : Nitrogen management (F)										
F ₁ : LCC 3	3.62	a	132.7	a	26.0	a	3.62	a	6.21	ab
F ₂ : LCC 4	2.80	b	101.8	b	23.0	c	2.68	c	7.01	a
F ₃ : Recommended practice (RP)	2.99	b	103.5	b	23.9	b	3.21	b	6.57	a
Farmers' practice (FP)	2.99	b	110.0	b	22.9	c	3.22	b	5.56	b
F^* - test	S		S		S		S		NS	
Treatment combinations (M×F) and C										
M ₁ F ₁	3.32	bc	127.1	a-c	26.2	a-c	3.64	a-c	5.56	c
M ₁ F ₂	2.88	bc	107.8	cd	22.3	h	2.86	d-f	6.25	bc
M ₁ F ₃	2.84	bc	99.3	cd	23.1	e-h	3.38	a-d	6.87	bc
M ₁ F ₂	4.54	a	144.4	a	26.7	a	3.86	a	5.56	c
M ₂ F ₂	2.48	bc	111.8	cd	22.7	f-h	3.14	c-f	5.97	bc
M ₂ F ₃	2.82	b	103.7	cd	22.9	f-h	2.65	e-g	6.53	bc
M ₃ F ₁	2.61	c	140.7	ab	26.4	ab	3.81	ab	6.33	bc
M ₃ F ₂	2.63	bc	92.0	d	22.5	gh	2.14	g	8.78	a
M ₃ F ₃	3.31	bc	113.0	b-d	25.0	b-d	3.51	a-c	6.03	bc
M ₄ F ₁	2.99	bc	118.6	a-d	24.7	b-e	3.26	a-d	7.42	ab
M ₄ F ₂	3.20	bc	95.5	d	24.3	d-g	2.58	fg	7.03	bc
M ₄ F ₃	2.98	bc	98.2	cd	24.3	e-f	3.30	a-d	6.86	bc
Farmers' practice (Control)	2.99	bc	110.0	cd	22.9	f-h	3.22	b-e	5.56	c
F^{**} - test (M× F) and C	S		S		S		S		S	

tive tillers m⁻² was counted at harvest stage. Leaf area was calculated *in situ* by measuring the leaf blade length (l) and width (w) at three stages.

$$\text{Leaf area} = K \times L \times W$$

k being the "adjustment factor", the value of which was 0.75. Weight of 10 randomly selected panicles was recorded and mean was worked out and expressed in grams. 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. One thousand grains were counted from the net plot grain yield of each treatment and their weight was recorded in grams. Grain and straw yields were recorded separately for each net plot area and expressed at 14% moisture

level. Using the data on dry matter production and nitrogen content in different plant parts, the nitrogen uptake was calculated using the formula.

$$\text{N uptake (kg ha}^{-1}\text{)} = \frac{\text{Percent N content} \times \text{biomass (kg ha}^{-1}\text{)}}{100}$$

Results and Discussion

Effect on growth and yield attributes

Plant height

Significant differences were not noticed in plant height among different organic sources and N-man-

Table 6. Available nitrogen status (kg ha^{-1}) of soil of rainfed lowland rice as influenced by organic sources and LCC based N management at various growth stages. 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	Maximum tillering	Panicle initiation	Flowering	Harvest			
M_1 : Farm yard manure (FYM) @ 10 t ha^{-1}	496	509	bc	490	b	480	ab
M_2 : Sunnhemp @ $10 \text{ kg seeds ha}^{-1}$	490	541	a	517	a	495	a
M_3 : Eupatorium @ 5 t ha^{-1}	495	523	ab	493	ab	477	ab
M_4 : No organics	502	492	cd	476	b	462	b
Farmers' practice (FP)	473	465	d	450	c	435	c
F^* - test	NS	S	b	S	S	S	S
F_1 : LCC 3	488	511	a	492	ab	477	ab
F_2 : LCC 4	511	538	b	509	a	491	a
F_3 : Recommended practice (RP)	488	502	c	481	b	468	b
Farmers' practice (FP)	473	465	d	450	c	435	c
F^* - test	NS	S	S	S	S	S	S
M_1F_1	490	500	a-e	480	b-d	470	a-c
M_1F_2	505	535	ab	518	ab	505	a
M_1F_3	493	492	b-e	472	b-d	465	a-c
M_2F_1	478	538	ab	517	ab	495	ab
M_2F_2	509	555	a	530	a	505	a
M_2F_3	482	530	a-c	505	a-c	485	ab
M_3F_1	490	525	a-c	500	a-c	480	ab
M_3F_2	500	542	ab	500	a-c	483	ab
M_3F_3	495	510	a-e	480	b-d	468	a-c
M_4F_1	495	480	c-e	473	b-d	462	a-c
M_4F_2	530	520	a-d	490	a-d	470	c
M_4F_3	480	475	de	465	cd	455	bc
Farmers' practice (Control)	473	465	e	450	d	435	c
F^{**} - test (Mx F) and C	NS	S	S	S	S	S	S

agement at maximum tillering and panicle initiation stages but it differed significantly at flowering stage (Table 2). Nitrogen management at LCC-3 showed significantly higher plant height at flowering stage compared to all other treatments and check. With advancement in age of crop, most of the combinations of organics and inorganics recorded greater plant height. Farmers' practice recorded lower plant height at all stages compared to other treatment combinations.

Number of tillers

Application of different organic manures significantly influenced the number of tillers per meter row length at all growth stages except at panicle initiation stage. At maximum tillering stage eupatorium application recorded significantly higher number of tillers than no organic treatment and was on par with other treatments and check (Table 3). Where as at flowering

stage sunhemp green manuring recorded maximum number of tillers. This is because during the initial stage of crop with sunnhemp green manuring was not superior due to simultaneous growth of green manuring crop but later the crop showed better growth after the incorporation of sunnhemp as indicated by higher tillering, which was due to creation of more space as reported by Sharma et al. [5] and narrow C: N ratio in sunhemp resulted in quicker decomposition and release of nutrients compared to other organic sources [6].

Nitrogen management at LCC-3 recorded higher tiller number than other at all the growth stages. However, it was on par with check at maximum tillering and with recommended practice at flowering stages. Among the treatment combinations, M_2F_1 i.e., *in-situ* green manuring with sunnhemp at LCC threshold value of 3 nitrogen management recorded higher tiller number than all other treatment combinations and

Table 7. Nitrogen uptake (kg ha⁻¹) of leaf, stem panicle and total of rainfed lowland rice as influenced by organic sources and LCC based N management. *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		Stem		Panicle		Total	
M ₁ : Farm yard manure (FYM) @ 10 t ha ⁻¹	31.6	ab	28.1	a	50.8		110.4	a
M ₂ : Sunnhemp @ 10 kg seeds ha ⁻¹	34.0	a	28.2	a	49.5		117.8	a
M ₃ : Eupatorium @ 5 t ha ⁻¹	33.1	a	28.3	a	49.8		111.2	a
M ₄ : No organics	27.8	b	27.8	a	47.0		102.5	b
Farmers' practice (FP)	18.0	c	24.4	b	49.6		92.9	c
<i>F</i> * - test	NS		NS		NS		NS	
F ₁ : LCC 3	33.9	a	29.1	a	56.1	a	119.1	a
F ₂ : LCC 4	33.1	a	27.2	a	42.2	c	102.6	b
F ₃ : Recommended practice (RP)	27.8	b	28.0	a	49.5	b	105.2	b
Farmers' practice (FP)	18.9	c	24.4	b	49.6	b	92.9	c
<i>F</i> * - test	S		NS		S		S	
M ₁ F ₁	36.9	ab	29.0	ab	56.0	a-c	121.9	ab
M ₁ F ₂	34.4	a-c	27.7	ab	44.1	d-g	106.2	c-f
M ₁ F ₃	23.6	ef	27.5	ab	52.2	a-d	103.3	d-f
M ₂ F ₁	41.1	a	30.4	a	59.5	a	131.0	a
M ₂ F ₂	34.7	a-c	26.4	ab	48.3	c-f	109.6	b-e
M ₂ F ₃	26.1	d-f	27.9	ab	40.9	e-g	94.9	ef
M ₃ F ₁	32.6	b-d	28.8	ab	58.6	ab	120.1	a-c
M ₃ F ₂	34.0	a-c	27.6	ab	36.7	g	98.2	ef
M ₃ F ₃	32.8	b-d	28.3	ab	54.1	a-c	115.3	b-d
M ₄ F ₁	25.2	ef	28.0	ab	50.3	a-e	103.6	d-f
M ₄ F ₂	29.5	b-e	27.1	ab	39.8	fg	96.5	ef
M ₄ F ₃	28.7	c-e	28.3	ab	50.9	a-d	107.4	c-f
Farmers' practice (Control)	18.9	f	24.4	b	49.6	b-e	92.9	f
<i>F</i> ** - test (Mx F) and C	S		NS		S		S	

check.

Leaf area

Green manuring with sunnhemp recorded significantly higher leaf area per plant at panicle initiation stage than check. While at flowering stage FYM application recorded significantly higher leaf per plant than other treatments except sunnhemp green manuring. Nitrogen management at LCC-3 recorded significantly higher leaf area per plant at all the growth stages, except with check at maximum tillering stage (Table 4). Among the treatment combinations leaf area differed significantly at all the growth stages. Leaf area was maximum with M₂F₁ i.e., *in-situ* green manuring with sunnhemp at LCC threshold value of 3 nitrogen management at all the growth stages, closely followed by recorded higher M₁F₁ and M₃F₁ [7].

Yield and yield attributes

Organics did not differ significantly with respect to

yield and yield attributes like panicle weight, filled grains per panicle, 1000 grain weight 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 panicle weight and 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 [8].

N- Management at LCC-3 recorded (3.64 t ha⁻¹) significantly higher grain yields than in LCC-4 (2.68 t ha⁻¹), recommended practice (3.21 t ha⁻¹) and check (3.22 t ha⁻¹) (Table 5). This may be attributed to increased yield attributes like panicle weight, filled grains per panicle and 1000 grain weight and growth parameters like plant height, number of tillers per plant and leaf area. These results are in conformity with the earlier findings [9—11]. 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.

Among the treatment combinations, M_2F_1 i.e., *in-situ* green manuring with sunnhemp at LCC threshold value of 3 nitrogen management recorded significantly higher panicle weight, filled grains per panicle and 1000 grain weight than other treatment combinations and check. This resulted in significantly higher grain yield (3.86 t ha^{-1}), closely followed by M_3F_1 (3.81 t ha^{-1}) which recorded 15.5 and 18.0% increased grain yield over recommended practice and farmers' practice. But the straw yield was significantly higher in M_3F_1 i.e., eupatorium green leaf manuring at LCC threshold value of 3 (8.78 t ha^{-1}) and lower straw yield was observed in M_1F_1 , M_2F_1 and Check (5.56 t ha^{-1}).

Effect on available N status
of soil N and uptake

Soil N status

All the organics at LCC-4 i.e., at higher fertilizer level showed increased availability of N at all growth stages over the initial status and recommended NPK application alone and check. However, this was on par with all organics at LCC-3 (Table 6). This clearly indicates that increased soil fertility with the use of organics along with chemical fertilizers. Increased N status with combined application of organics and inorganics compared to recommended NPK application alone has been reported by several workers [12].

Among the organics, green manuring with sunnhemp gave higher available N at later stages (panicle initiation, flowering and at harvest). Loss of N from green manures is less, as leguminous green manures possess strong ability to fix atmospheric N, absorb available nutrients from soil and help in concentrating plant nutrients in the surface layer of soil [12]. Availability of N in soil increased with increase in fertilizer application (LCC-4) but due to excessive lodging, it did not result in increased grain yield. Thus, the N management at LCC threshold value of 3 was found to be optimum for Intan rice.

N uptake

Higher total N uptake of 131, 120.1 and 121.9 kg ha^{-1} (Table 7) were recorded with green manuring of sunnhemp and eupatorium and FYM i.e., with different organic manures incorporated plots, respectively at LCC-3 than other treatment combinations. Increased N uptake may be due to increased availability of soil N under green manuring and FYM application. These findings are in line with earlier [12–14].

Higher N uptake with green manuring might be due to higher N content of green manure crops as noticed by several workers [15] and less loss of N with green manuring [15, 16].

Conclusion

Nitrogen application should coincide with crop growth and its requirement. Critical or threshold LCC values are known as those that help to optimize the N application and thus helps in realizing better grain yield and help in reducing the loss of chemical fertilizers. In the present experiment, N management at LCC-3 with sunnhemp green manuring seems to be more promising with respect to grain yield as a result of higher available soil N and enhanced growth and yield attributes followed by green leaf manuring with eupatorium with N management at LCC-3. Thus, the N management at LCC threshold value of 3 was found to be optimum for Intan rice.

References

1. Anonymous (2014) Agricultural Statistics at a Glance 2014. Government of India Ministry of Agriculture Department of Agriculture and Cooperation Directorate of Economics and Statistics.
2. 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 : 649–665.
3. Nath DK, Haque F, Amin F, Islam MSh, Salequ MA (2013) Farmers' participatory site specific nutrient management in gangetic tidal floodplain soil for high yielding boro rice (*Oryza sativa* L.). *Agriculturists* 11 : 8–14.
4. Witt C, Pasuquin JMCA, Mutters R, Buresh RJ (2005) New leaf color chart for effective nitrogen management in rice. *Better Crops* 89 : 36–39.
5. Sharma R (2013) Effect of long term integrated nutri-

- ent management system on soil and crop productivity in rice-wheat crop sequence. PhD Dissertation, pp 155.
6. Kumar N, Mina BL, Chandra S, Srivastva AK (2011) Nutr Cycl Agroecosyst 90 : 369.
 7. 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.
 8. Morteza Siavoshi, Alireza Nasiri, Shankar L Laware (2011) Effect of organic fertilizer on growth and yield components in rice (*Oryza sativa* L.). J Agric Sci 3 : 217—224.
 9. Khursheed S, Arora S, Ali T (2013) Effect of organic sources of nitrogen on rice (*Oryza sativa* L.) and soil carbon pools in inceptisols of Jammu. Columbia International Publishing. Int J Environ Poll and Solutions 1 : 17—21.
 10. Larijani BA, Hoseini SJ (2012) Comparison of integrated chemical and organic fertilizer management on rice growth and yield under System of Rice Intensification (SRI). Int J Agron and Pl Prod 3 : 726—731.
 11. Salman D, Morteza S, Dariush Z (2012) Application of nitrogen and silicon rates on morphological and chemical lodging related characteristics in rice (*Oryza sativa* L.) at North of Iran. J Agric Sci 4 (In press).
 12. Kumar A, Meena RN, Yadav L, Gilotia YK (2014) Effect of organic and inorganic sources of nutrient on yield, yield attributes and nutrient uptake of rice. Rice, Cv Prh-10. Int Quart J Life Sci 9 : 595—597.
 13. Mehdi SM, Sarfraz M, Abbas ST, Shabbir G (2011) Integrated nutrient management for rice-wheat cropping system in a recently reclaimed soil. Soil Environ 30 : 36—44.
 14. Virdia HM, Mehta HD (2009) Integrated nutrient management in transplanted rice (*Oryza sativa* L.). J Rice Res 2 : 99—104.
 15. Yadav MP, Aslam M, Kushwaha SS (2005) Effect of integrated nutrient management on rice (*Oryza sativa*) wheat (*Triticum aestivum*) cropping system in central plainzone of Uttar Pradesh. Ind J Agron 50 : 89—93.
 16. Zayed BA, Elkhoby WM, Salem AK, Ceesay M, Uphoff NT (2013) Effect of integrated nitrogen fertilizer on rice productivity and soil fertility under saline soil conditions. J Pl Biol Res 2 : 14—24.