Critical Leaf Color Chart Level and N Determination for Rice Production in Fogera Plain

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Abstract

*Assessment of nitrogen status in standing crop and its application according to the crop need is a best approach to reduce the loss. Leaf Color Chart (LCC) is one of the best methods for monitoring leaf N status. Field experiment was conducted at Fogera plain for two years in 2019 and 2020 main cropping seasons to determine the critical LCC value of X-Jigna rice variety and the level of appropriate N rate to be applied at the critical LCC. The treatments included a factorial combination of four levels of LCC cv. (LCC cv. 1, 2, 3, and 4) with different rates of N application (20, 25, 30 and 35 kg ha^{-1} at a time) along with two checks {(control (0 kg N ha^{-1}), and recommended N (276 kg N ha^{-1} in two splits*1/3 at planting + 2/3 at maximum tillering)}. The statistical analysis indicated that dry biomass and grain yields were significantly affected by the interactions of the LCC values and the N rates. The LC4+35 kg N ha^{-1} treatment was found to give statistically equivalent grain and biomass yields compared to the recommended N rate (276 kg ha^{-1}) with the reduction of 101 kg (36.6%) N. The economic analysis indicated that highest Net Benefit (Birr 64,975.46/ha) with 652.155% Marginal Rate of Return was obtained at the LCC4 combined with 35 kg ha^{-1} N. The application of nitrogen to rice at the rate of 35 kg ha^{-1} N whenever the leaf color of the rice plant matching the value of LCC4 is recommended for rainfed lowland rice production in Fogera for X-Jigna variety.*

Keywords: Lowland Rice, N loss, leaf N, Leaf Color Chart.

Introduction

Rice (*Oryza sativa* L.) is one of the major staple foods for half of the world population (Mohidem et al., 2022). In Ethiopia, rice production was started three decades ago in the early 1970's and the country has reasonable potential to grow various rice types mainly in rain fed lowland, upland and irrigated ecosystems (Mulugeta and Heluf, 2014). Though rice is a recent introduction to the country, its importance is well recognized as the production area coverage of about 10,000 ha in 2006 has increased to over 63,000 ha in 2018 (CSA 2019). According to MoA (2020), rice is recognized as a "millennium crop" for Ethiopia with scopes for high job creation potential and significance on food security especially in places where other food crops like tef, maize, wheat and sorghum do not do well. Among the existing production ecologies, 81.2% is rain-fed lowland, 18.6% rain-fed upland and 0.2% is irrigated. The country has a potential of nearly 6million hectare for rain-fed and 3.7 million hectares irrigated rice production potential (MoA, 2020).

Nitrogen is an essential nutrient for rice production in sustaining high yields (Subedi and Panta, 2018). The nutrient is required for chlorophyll formation which gives the leaves green color and enables the plants to gain energy for nutrient uptake and growth (Subedi and Panta, 2018). Rice crop usually take half of the applied N for grain yield and above ground biomass. The other half of the N is lost via ammonium volatilization, denitrification, runoff, and leaching dissipated in the water and environment causing a number of ecological problems (Houshmandfar and Anthony, 2011; Nacjimuthu *et al.*,2007). The applied nitrogen is lost due to lack of synchronization of the time between the nitrogen demand and nitrogen supply (Sen *et al*., 2011). Conversely, inadequate N uptake results in reduced yield and profit. Fixed time recommended N split applications at specified growth stages is the most common practice followed by the farmers (Houshmandfar and Anthony, 2011). However; application of nitrogen in splits, may produce optimum yields, but cannot help increase N use efficiency beyond a limit as the nutrient is not synchronized with crop demand, as well as the use of nitrogen in excess to the requirement (Subedi and Panta, 2018; Reena *et al*., 2017). Therefore, there is a need to relook in to our traditional method of fertilizer recommendation.

Different techniques are available in nutrient nitrogen management to tailor the supply of the nutrient for the target yield besides enhancing use efficiency of applied fertilizers (Chittapur *et al*., 2015). Real time (also called need based) nitrogen management requires periodic assessment of nitrogen status in standing crop and its application according to the crop need and with the time of fertilizer application (Subedi and Panta, 2018; Reena *et al*., 2017). As leaf N content is closely related to photosynthetic rate and biomass production, it is a sensitive indicator of the dynamic changes in crop N demand during a growing season (Houshmandfar and Anthony, 2011). The direct measurement of leaf N concentration by laboratory procedure is laborious, time consuming and costly (Houshmandfar and Anthony, 2011). Such procedures have limited use as a diagnostic tool for optimizing N top dressing because of the extensive time delay between sampling and obtaining results (Houshmandfar and Anthony, 2011). Two simple, quick and non-destructive tools available for in situ monitoring of leaf N status in rice and other crops are the chlorophyll meter, also known as SPAD (soil plant analysis development) meter, and the Leaf Color Chart (LCC) (Houshmandfar and Anthony, 2011). SPAD is a chlorophyll metering device that can provide a quick estimate of the leaf N status, but it is relatively expensive (Houshmandfar and

Anthony, 2011). The Leaf Color Chart (LCC) on the other hand is cheap, simple, and an easy-to-use alternative to monitor the relative greenness of the rice leaf as an indicator of crop N status (Houshmandfar and Anthony, 2011). The concept is based on results that show a close link between leaf chlorophyll content and leaf N content. The first LCC was developed in Japan (Islam *et al*., 2007). Chinese researchers developed a modified LCC and calibrated it for indica, japonica, and hybrid rice (Islam *et al*., 2007). The commonly used LCC was developed from a Japanese protype by the Crop and Resource Management Network (CREMNET) at IRRI and the Philippine Rice Research Institute, Philippines (Philrice) (Islam *et al*., 2007; Nacjimuthu *et al*.,2007). LCC has been tested for real time N management in the farmers' fields in several countries (Sudhalakshmi, *et al*., 2008). LCC has been successfully used for rice and wheat (Houshmandfar and Anthony, 2011). Several experimenters reported LCC as a best way of real time N management considering higher grain yield and N saving in rice (Budhar, 2005; Balaji and Jawahar, 2007 and Sathiya and Ramesh, 2009). The LCCs used in Asia are typically a durable plastic strip about 7 cm wide and 13 to 20 cm long, containing shades of green from yellowish green (No. 1) to dark green (No. 7) and is calibrated with the SPAD meter (Chittapur *et al*., 2015; Houshmandfar and Anthony, 2011). With a real-time approach to N management, farmers monitor the color of rice leaves at 7 to 10 days intervals and apply N fertilizer whenever leaves become more yellowish green than the critical color on the LCC (Houshmandfar and Anthony, 2011).

Critical or threshold value of the LCC is defined as the intensity of green color that must be maintained in the uppermost fully opened leaf of the crop plant (Chittapur *et al*., 2015). At critical/ predetermined stage of crop a calibrated dose of fertilizer N needs to be replenished whenever leaf greenness is below the critical LCC threshold (Chittapur *et al*., 2015). Thus, maintaining the leaf greenness just above the LCC critical value ensures high yields with need-based N applications thereby leading to high fertilizer N use efficiency (Chittapur *et al*., 2015). Farmers will benefit hugely if they can adjust N application through LCC as an indicator of actual crop condition and nutrient requirement (Chittapur *et al*., 2015). Nacjimuthu *et al*. (2007) reported a nitrogen fertilizer save of 50% by the use of LCC compared to the conventional N application method. The LCC could be adopted to save 20-50 kg N/ha particularly in crops with greater N demand or in crops grown under environment prone to N loss (Chittapur *et al*., 2015; Houshmandfar and Anthony, 2011). Nitrogen management based on LCC cv. 4 helped to avoid excess application of nitrogen to rice and reduced nitrogen requirement from 12.5 to 25% without causing yield reduction (Subedi and Panta, 2018). Chittapur *et al*., (2015) indicated that LCC was originally developed for rice was found handy in other cereals/grasses such as maize, wheat, sugarcane and others (Figure 1). Reena *et al*., (2017) reported that application of nitrogen at a rate of 105 kg /ha based on LCC value (4 and 5) resulted in statistically similar growth and yield of wheat compared with recommended practice (150 kg N/ha) saving 45 kg /ha nitrogen.

Figure 1. Leaf Color Chart as used for different crops

The topmost fully expanded leaf is chosen for leaf color measurement as it is highly correlated to the N status of rice plants. The color of a single leaf is measured by holding the LCC vertically and placing the middle part of the leaf in front of a color strip for comparison (Sudhalakshmi, *et al*., 2008). The leaf should neither be detached nor destroyed. The leaf in which reading to be recorded is to be shielded with our body as the leaf colour chart reading is affected by sun's angle and sunlight intensity (Sudhalakshmi, *et al*., 2008). The reading should be taken on a clear sunny day between 0900 and 1100 or 1400 and 1600 with the sun at your back to shade the leaf being measured (Sudhalakshmi, *et al*., 2008). Readings should not be taken very early in the morning since dew drops can make reading difficult (Sudhalakshmi, *et al*., 2008). LCC readings are taken once in a week, starting from 14 days after transplanting for transplanted rice and 21 days after seeding for direct seeded rice (Sudhalakshmi, *et al*., 2008). The critical leaf color reading for N top dressing may normally range from 3 to 5 depending upon the cultivar groups and 4 is the best optimum for most (Sudhalakshmi, *et al*., 2008). If more than 5 leaves show reading below the critical value, nitrogenous fertilizer has to be applied (Sudhalakshmi, *et al*., 2008). If the color falls between two grades, the mean of the two values is taken for LCC readings (Sudhalakshmi, *et al*., 2008).

The use of LCC for scheduling N application may not be uniformly applicable to all varieties that differ in inherent leaf color and regions that differ in climate, thereby necessitating individual or group standardization in different cultivated areas (Houshmandfar and Anthony, 2011). Identification of correct threshold values of the LCC is essential as they differ according to location, season, variety, and rice ecosystem (Ahmad *et al*., 2016). Critical LCC values vary considerably among different rice genotypes having different genetic background and leaf colour (Sen *et al*., 2011). The critical LCC value should be determined for distinctively varying rice varieties (Sen *et al*., 2011). After assessing LCC values for different rice varieties, Sen *et al*., (2011) reported higher grain yield along with corresponding higher agronomic and recovery efficiency and other parameters LCC < 5 for NDR 359, Sarju 52 and ≤ 4 for HUBR 2-1 rice varieties. Based on their experiment in Iran, Houshmandfar and Anthony (2011) reported that though the two rice varieties they consider have equal critical LCC value of 4, one variety named Tarom-Hashemi need 25 kg N ha^{-1} while the variety GRH-1 need the application of 35 kg N ha^{-1}. There is no previous research effort of determining critical LCC values of rice in the case of Ethiopia for managing nitrogen nutrient application. The present experiment is therefore initiated to determine the critical LCC value of X-Jigna variety and to determine the level of appropriate N rate at the critical LCC.

Materials and Methods

The field experiment was conducted at Fogera district in the rainy seasons of 2019 and 2020 at two sites for each year. The experimental site is located between Latitude 11°49’55 North and Longitude 37° 37′ 40 East at an altitude of 1815 meters above sea level. The study site receives averages mean annual rainfall, minimum and maximum temperature of 1219 mm, 12.75°C and 27.37°C, respectively. The long-term rainfall data (1991-2021) years indicated that the sudy area receives much of the rainfall in July and August (Figure 2).

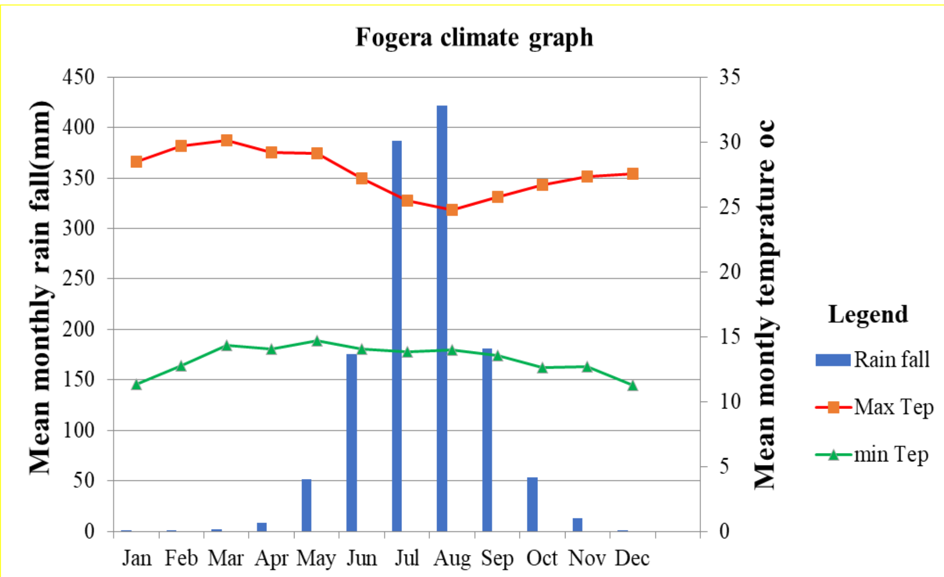

Figure 2. The Rainfall and Temperature condition of Fogera for the period 1991-2021

The experimental sites soil was found to be heavy clay with pH range of 5.87-6.63, which is slightly acidic and it is a preferred range for most crops (Table 1). Total nitrogen content (%) was with range of 0.09-0.16, which is within the range of low levels (0.02-0.5%) for tropical soils (Landon, 1991). The organic matter content of the soil was between 2.13-3.09%, which is within a range of medium (2-4%) for Ethiopian soils as per criteria developed by Murphy (1968). The available P content of the experimental sites soil was between 20.5-22.13 mg kg^{-1}, which lies in a range of deficiency (< 20-40 mg/kg) for most crops (Landon, 1991).

Table 1. Relevant soil physicochemical properties of the experimental rice field before planting in Fogera of Ethiopia

Soil properties	Units	Minimum Value	Maximum value	Method and Reference
Textural class		Heavy clay		Bouyoucos hydrometer method (Bouyoucos, 1951)
Sand	%	30		
Silt	%	10		
Clay	%	60		
Soil chemical properties		-		
pH (H_2O) 1:2.5 g soil	-	5.87	6.63	
Total nitrogen (TN)	%	0.09	0.16	Kjeldahl digestion method (Havlin *et al*. 1999)
Organic carbon (OC)	%	1.24	1.93	Walkley–Black wet digestion process (Walkley and Black, 1934)
Available Phosphorus	mg kg^{-1}	20.5	22.13	Olsen NaHCO3 extraction method (Tekalign Tadese *et al*., 1991)

Treatments were arranged in factorial arrangement in randomized complete block design with three replications. The treatments included four levels of LCC cv. (LCC cv. 1, 2, 3, and 4) with different rates of N application (20, 25, 30 and 35 kg ha^{-1} at a time) along with control (0kg Nha-1) and recommended N (276 kg N ha^{-1} with two splits:1/3 at planting, 2/3 at maximum tillering)}. All the plots receive equal amount of phosphorous at rate of 69 kg ha^{-1} P_2O_5. The widely produced X-Jigna variety was used at the rate of 100 kg ha^{-1} P_2O_5.

Leaf colour chart (LCC) measurement was conducted following the recommended steps. LCC consisting of four green shades from yellowish green to dark green, showing increasing greenness with increasing number (1=Yellowish, …. 4=Deep green), were used in the study. LCC readings were measured every week from 21 Days After Sowing (DAS) to heading. Ten disease-free rice plants were randomly selected in the plot, and the color of the youngest fully expanded leaf of the selected plant were compared by placing its middle part on top of the color strip in the chart. If 6 or more leaves read equal or below the treatments critical value (LCC of the respective TRTs), a dose of N kg ha^{-1} (depending on the N TRT) were applied for each plot.

Table 2. Total N applied to the respective treatments during the experiment

N Management	N application frequency	Total N (kg/ha)
LC1-N20	4	80
LC2-N20	5	100
LC3-N20	5	100
LC4-N20	5	100
LC1-N25	3	75
LC2-N25	4	100
LC3-N25	5	125
LC4-N25	5	125
LC1-N30	2	60
LC2-N30	3	90
LC3-N30	4	120
LC4-N30	5	150
LC1-N35	2	75
LC2-N35	3	105
LC3-N35	4	140
LC4-N35	5	175
C1(0-69NP)	0	0
C2(N-276+P69)	2	276

Agronomic data on plant height, number of effective tillers, grain yield, straw yield, thousand seeds weight and harvest index were collected depending on the specific crop character and statistical analysis was performed using the statistical analysis system (SAS) software version 9.2 (SAS-Institute 2008). Whenever the F-test showed significant difference among treatments for a parameter in question, mean separation of treatments was performed using least significant difference (LSD) method.

To assess the profitability of the treatments, cost-benefit analysis was carried out by following the CIMMYT partial budget analysis method (CIMMYT 1988). The prevailing cost of inputs and out puts in year 2020 considered for the analysis. Respective prices of rice grain (Birr 16 per kg) and straw (Birr 2.0 per kg), the cost of Urea and NPS fertilizers for the stated period at Fogera were Birr 13.1 and 14.3, respectively.

Results and Discussion

Growth, yield and yield components

The total N applied during the experimental period was added keeping the records of N applications based on observations of the corresponding LCC values for each treatment (Table 2). The most frequent (five times) and highest total N application (175 kg ha^{-1}) was done for the LC4 value and the 35 kg ha^{-1} N application rate. However, the total N applied for the LC4+35 kg ha^{-1} treatment was much lower than the previous recommended rate of 276 kg ha^{-1} N with the reduction of 101 kg N (36.6%).

The statistical analysis indicated that all of the rice growth parameters namely; plant height, panicle length, number of fertile grains per panicle, number of effective tillers, dry biomass yield, grain yield, thousand seeds weight and harvest index were significantly (P <0.05) affected by the treatments (Table 3). The comparison of plant height among the treatments showed that the highest plant height (83.47 cm) was recoded from 276 kg ha^{-1} N application which is statistically at par with the treatment of combined application of LCC4 with 35 kg ha^{-1} N and many other treatments (Table 4). The lowest plant height of 73.22 cm was observed at the no N fertilizer application which is found to be statistically equivalent with many of the treatments related to the LCC2 and LCC1 values.

Table 3. Analysis of variance (ANOVA) for Yield and yield components of rice

Source of variation	Df	Mean Square							
		PH (cm)	PL (cm)	NFGPP	ET/m2	DBY (tha^{-1})	GY (t ha^{-1})	TSW (g)	HI (%)
Treatment (T)	17	83.46*	2.42*	331.03*	0.024691**	49.45**	7.86**	14.90**	99.40**
Location (L)	3	1760.22**	31.12**	38654.35**	100.23**	12.28**	0.81**	182.4**	33.60NS
L x T	51	14.57NS	1.40NS	124.29NS	33.16NS	4.27NS	0.35NS	1.92NS	34.99NS
CV		5.23	6.77	19.65	13.59	20.89	12.14	6.85	16.81

PH=Plant Height, PL= Panicle length, NFGPP=Number of Fertile Grains Per Panicle, ET= Number of Effective Tillers per 1m row, DBY=Dry Biomass Yield, GY= Grain Yield, TSW= Thousand Seeds Weight, HI= Harvest index. * and ** designate significant difference at 5 and 1%, respectively. NS designate statistically non-significant effect at 5% probability level.

Regarding the number of effective tillers, the highest values were recorded for the LCC4 values at the N rates of 30 and 35 which were not significantly different from the N-276 kg ha^{-1} N control treatment and most others having the highest LCC and N rates (Table 4). Similarly, for the case of fertile grains per panicle, the highest number (81.8) was exhibited at the treatment of combined application of LCC4 with 35 kg ha^{-1} N which was statistically similar with 276 kg ha^{-1} N application and many of the others related with LCC4 and LCC3 values as well as higher N rates (Table 4). The statistically lower from the best scoring but equivalent with many treatments of corresponding to lower LCC and N rate treatments was recorded from the control treatment of no N application. In a similar fashion to the other growth parameters statistically higher panicle length of 18.35 cm was associated with the LCC4 combined to 35 kg ha^{-1} N being at par with the lengths of the 276 kg ha^{-1} N applied control treatment and the other treatments with higher LCCs combined with higher N rates (Table 4).

In agreement to the current finding, Sathiya and Ramesh, (2009) reported that growth parameters like plant height, and number of tillers, number of filled grains per panicle of rice were positively influenced by treatments and higher values were obtained with nitrogen application based on LCC value of 4 as compared to LCC value 3. Satpute *et al*., (2015); Chaudhary *et al*., (2018); and Subedi *et al*., (2017) had also reported significant responses of rice growth parameters due to N management by LCC compared to conventional nitrogen application method.

The statistical analysis for the dry biomass and grain yields, thousand seeds weight and harvest index showed that there was significant (P<0.05) response to the treatments (Table 3). Highest and statistically significant dry biomass yields of 12.86 and 12.04 t ha^{-1} were attained at the 276 kg ha^{-1} N applied control and the LCC4 combined to 35 kg ha^{-1} N treatments, respectively (Table 5). Similar to the biomass, the stated treatments showed the highest grain yields of 5.14 and 5.09 t ha^{-1}, respectively (Table 5). The lowest grain (2.03 t ha^{-1}) and biomass yields (5.47 t ha^{-1}) were obtained from treatments without N. A tendency of lower grain and biomass yields were observed with the lowest LCC and N values. With the reduction of 101 kg (36.6%) N from the control treatment of the 276 kg ha^{-1} N, the LCC4 combined to 35 kg ha^{-1} N found to give statistically equivalent grain and biomass yields. In line with this finding, Nacjimuthu *et al.* (2007) reported use of LCC compared to conventional N application method saved a nitrogen fertilizer of 50%. Subedi and Panta, (2018) had also stated that nitrogen management based on LCC cv. 4 helped to avoid excess application of nitrogen to rice and reduced nitrogen requirement from 12.5 to 25% with no yield reduction.

Table 4. Effects of N management using LCC on rice growth components

Treatments	Plant height (cm)	Number of Effective Tillers per 1m row	Panicle length (cm)	Number of Fertile Grains Per Panicle
LC1-N20	75.50^{cd}	41.5^{d}	16.90^{c}	60.67^{b}
LC2-N20	78.98^{abcd}	48.0^{abc}	17.03^{bc}	62.47^{ab}
LC3-N20	75.65^{cd}	49.33^{ab}	17.03^{bc}	62.07^{b}
LC4-N20	80.02^{abc}	49.5^{abc}	17.50^{abc}	65.00^{ab}
LC1-N25	79.43^{abc}	49.0^{abc}	17.35^{abc}	61.57^{b}
LC2-N25	77.53^{abcd}	44.33^{dc}	17.68^{abc}	62.27^{ab}
LC3-N25	79.40^{abc}	45.50^{bcd}	17.53^{abc}	63.10^{ab}
LC4-N25	80.93^{abc}	50.0^{abc}	17.18^{bc}	67.13^{ab}
LC1-N30	77.75^{abcd}	47.167^{abcd}	17.53^{abc}	68.37^{ab}
LC2-N30	80.87^{abc}	48.33^{abc}	17.43^{abc}	65.63^{ab}
LC3-N30	81.70^{abc}	47.33^{abcd}	17.33^{abc}	67.40^{ab}
LC4-N30	80.87^{abc}	47.83^{abc}	17.78^{abc}	70.10^{ab}
LC1-N35	76.57^{bcd}	49.66^{abc}	18.0^{abc}	67.30^{ab}
LC2-N35	75.87^{cd}	51.3^{ab}	18.10^{ab}	64.67^{ab}
LC3-N35	80.37^{abc}	53.0^{a}	18.01^{abc}	70.03^{ab}
LC4-N35	82.17^{ab}	53.0^{a}	18.35^{a}	81.80^{a}
C1(0 + 69P)	73.22^{d}	46.667^{abcd}	16.85^{c}	58.10^{b}
C2(N-276+P69)	83.47^{a}	50.83^{ab}	18.12^{ab}	74.40^{ab}
CV (%)	5.23	13.59	6.77	19.65

Working on wheat, Reena *et al*., (2017), similarly reported that application of nitrogen at rate of 105 kg /ha based on LCC value (4 and 5) resulted in statistically similar growth and yield of wheat compared with recommended practice (150 kg/ha) saving 30% (45 kg/ha) nitrogen. Comparison of the treatments with respect to thousand seeds weight showed the highest (29.25 g) weight was recorded from the LCC3 combined with 35 kg ha^{-1} N (Table 5). Most of the treatments were showing statistically non-significant thousand seed weight compared to the best scoring treatment except the lowest scoring (25.47 g) treatment of the one without N fertilizer application of course it is also having other statistically at par treatments that are either at the lower values of LCC or N or both combined. Harvest index is a parameter of yield analysis comparing the most economic factor (the grain yield) compared to the total above ground biomass yield. The analysis of variance had indicated that the treatments of LCC3 combined with 20 kg ha^{-1} N and LCC3 combined with 25 kg ha^{-1} N resulted in the highest harvest indices. Few of the treatments showed statistically at par but most of the treatments exhibiting statistically lower harvest indices compared to the best scoring ones (Table 5).

Table 5. Effects of N management using LCC on rice yield dry biomass, grain yield, thousand seeds weight and harvest index

Trtment	N- split	N rate applied (kg ha^{-1})	Dry Biomass Yield (tha^{-1})	Grain Yield (t ha^{-1})	Thousand Seeds Weight (g)	Harvest Index (%)
LC1-N20	4	80	7.24^{cdef}	2.51^{gh}	28.57^{abc}	34.7^{dc}
LC2-N20	5	100	8.60^{bcde}	2.92^{def}	27.95^{abcd}	33.9^{d}
LC3-N20	5	100	8.01^{bcdef}	3.56^{bcd}	28.38^{abc}	44.4^{a}
LC4-N20	5	100	8.88^{bcde}	3.60^{bcd}	28.95^{ab}	40.5^{abcd}
LC1-N25	3	75	6.32^{ef}	2.66^{fg}	28.62^{abc}	42.1^{ab}
LC2-N25	4	100	8.54^{bcde}	2.96^{def}	28.27^{abc}	35.0^{dc}
LC3-N25	5	125	9.17^{bcd}	3.99^{b}	28.35^{abc}	44.0^{a}
LC4-N25	5	125	10.73^{b}	4.01^{b}	29.25^{ab}	37.4^{bcd}
LC1-N30	2	60	6.99^{def}	2.70^{gf}	26.72^{bcd}	39.0^{abcd}
LC2-N30	3	90	9.64^{bcd}	3.46^{bcde}	27.93^{abcd}	36.0^{bcd}
LC3-N30	4	120	10.12^{b}	3.91^{bc}	29.70^{a}	38.6^{abcd}
LC4-N30	5	150	10.14^{b}	3.96^{b}	27.87^{abcd}	39.0^{abcd}
LC1-N35	2	75	7.59^{bcdef}	3.23^{def}	25.87^{cd}	37.1^{bcd}
LC2-N35	3	105	9.63^{bcd}	3.57^{bcd}	27.60^{abcd}	41.18^{abc}
LC3-N35	4	140	9.97^{cb}	3.64^{bcd}	29.25^{ab}	36.5^{bcd}
LC4-N35	5	175	12.04^{a}	5.09^{a}	28.85^{ab}	42.30^{ab}
C1(0 + 69P)	0	0	5.47^{f}	2.03^{h}	25.47^{d}	37.1^{bcd}
C2(N-276+P2O5-69)	2	276	12.86^{a}	5.14^{a}	27.13^{abcd}	39.97^{abc}
CV (%)			20.89	12.14	6.85	16.81

In accordance with the present observation, Sathiya and Ramesh (2009) claimed that productivity of rice with respect to grain and straw yield as well as harvest index was significantly influenced by nitrogen management treatments. They found higher grain and straw yields with nitrogen application based on LCC value of 4 compared to LCC value 3. Satpute *et al*., (2015) and Subedi *et al*., (2017) had stated that significant responses of test weight and harvest index of rice under different levels of LCC values.

The improvement in the yield attributes of rice is might be due to the adequate supply of photosynthates to sink under higher levels of nitrogen (Chaudhary *et al*., 2018). Availability of adequate quantity of nitrogen during critical stages of plant growth might have resulted in better growth characters and yield components at various phenological stages and finally on the yield of rice (Sathiya and Ramesh, 2009). Leaf nitrogen status of rice is closely related to photosynthetic rate and biomass production, and it is a sensitive indicator of changes in crop nitrogen demand within a growing season. Application of fertilizer nitrogen based on leaf color chart was found effective to maintain optimal leaf nitrogen which resulted in better crop growth and high rice grain yield (Sathiya and Ramesh, 2009).

Economic analysis

Following the CIMYYT (1988) partial budget analysis method, grain and straw yield adjustments, calculations of total variable costs (TVC), gross benefits (GB) and net benefits (NB) were performed (Table 6). Dominance analysis was carried after arranging the treatments in their order of TVC. A treatment will be considered as dominated if it has higher TVC but lower NB than a previous treatment with lower TVC and higher NB (Table 7). Non dominated treatments were taken out and marginal rate of return (MRR) was computed (Table 8). According to the CIMYYT (1988) partial budget analysis methodology, treatments exhibiting the minimum or more MRR (>100%) will be considered for the comparison of their NB. Highest NB (Birr 64,975.46/ha) with acceptable level of MRR (652.155%) was observed at the LCC4 combined to 35 kg ha^{-1} N (Table 8). Cognizant to the current result, Iqbal et al., (2016) reported maximum net income (Rs.153,063 ha^{-1}) was recorded in LCC technique compared to farmers practice (Rs.141,050 ha^{-1}). The authors concluded that LCC is an easy technique to use and cost-effective apparatus for monitoring chlorophyll of leaf and improving nitrogen fertilizer management in rice. The application of nitrogen to rice at the rate of 35 kg ha^{-1} N whenever the leaf color of the rice plant matching the value of LCC4 is to be recommended for rainfed lowland rice production in Fogera district using the X-Jigna variety.

Table 6. Grain and straw yield adjustments, total variable cost, gross and net benefit analysis

N Management	Adjusted Grain Yield (kg/ha)	Adjusted Straw Yield (kg/ha)	Total N applied (kg/ha)	Total Urea (Kg/ha)	TVC (Birr/ha)	GB (Birr/ha)	NB (Birr/ha)
LC1-N20	2259	4257	80	173.9	2857.4	36882.0	34024.6
LC2-N20	2628	5112	100	217.4	3571.7	43146.0	39574.3
LC3-N20	3204	4005	100	217.4	3571.7	49261.5	45689.8
LC4-N20	3240	4752	100	217.4	3571.7	50868.0	47296.3
LC1-N25	2394	3294	75	163.0	2678.8	37260.0	34581.2
LC2-N25	2664	5022	100	217.4	3571.7	43497.0	39925.3
LC3-N25	3591	4662	125	271.7	4464.7	55471.5	51006.8
LC4-N25	3609	6048	125	271.7	4464.7	57793.5	53328.8
LC1-N30	2430	3861	60	130.4	2143.0	38596.5	36453.5
LC2-N30	3114	5562	90	195.6	3214.6	50382.0	47167.4
LC3-N30	3519	5589	120	260.9	4286.1	55890	51603.9
LC4-N30	3564	5562	150	326.1	5357.6	56457.0	51099.4
LC1-N35	2907	3924	75	163.0	2678.8	45130.5	42451.7
LC2-N35	3213	5454	105	228.3	3750.3	51556.5	47806.2
LC3-N35	3276	5697	140	304.3	5000.4	52771.5	47771.1
LC4-N35	4581	6255	175	380.4	6250.5	71226.0	64975.5
C1(0-69NP)	1827	3096	0	0	0	29308.5	29308.5
C2(N-276+P69)	4626	6948	276	600.0	9858	72873.0	63015.0

Table 7. Dominance Analysis

N Management	TVC (Birr/ha)	NB (Birr/ha)	
C1(0-69NP)	0	29,308.5	
LC1-N30	2143.0	36,453.5	
LC1-N25	2678.8	34,581.2	D
LC1-N35	2678.8	42,451.7	
LC1-N20	2857.4	34,024.6	D
LC2-N30	3214.6	47,167.4	
LC2-N20	3571.7	39,574.3	D
LC3-N20	3571.7	45,689.8	D
LC4-N20	3571.7	47,296.3	
LC2-N25	3571.7	39,925.3	D
LC2-N35	3750.3	47,806.2	
LC3-N30	4286.1	51,603.9	
LC3-N25	4464.7	51,006.8	D
LC4-N25	4464.7	53,328.8	
LC3-N35	5000.4	47,771.1	D
LC4-N30	5357.6	51,099.4	D
LC4-N35	6250.5	64,975.5	
C2(N-276+P69)	9858.0	63,015.0	D

D= Dominated treatment

Table 8. Marginal Rate of Return (MRR) Analysis

N Management	TVC (Birr/ha)	NB (Birr/ha)	MRR (%)
C1(0-0NP)	0	29,308.50	
LC1-N30	2143.043	36,453.46	333.40
LC1-N35	2678.804	42,451.70	1,119.57
C2-N30	3214.565	47,167.43	880.19
LC4-N20	3571.739	47,296.26	36.07
LC2-N35	3750.326	47,806.17	285.53
LC3-N30	4286.087	51,603.91	708.85
LC4-N25	4464.674	53,328.83	965.87
LC4-N35	6250.543	64,975.46	652.15

Conclusions

Monitoring rice plant N status is a valid approach for balancing the crop N demand and N supply from soil and applied fertilizer. In many field situations, more than 50% of applied N is lost due in part to the lack of synchrony of nutrient N demand and supply. The LCC is an easy-to-use simple tool that can help farmers to avoid over as well as under application of N in rice plant. The LCC based nitrogen nutrient management in rice can be used to save the nutrient loss with no yield reductions. Thus, there is considerable opportunity to increase rice yield and economic advantage through improved N management with the LCC. The critical LCC value of 4 with 35 kg N ha^{-1} for X-Jigna variety was found to be the best N management option for guiding N application to achieve equivalent grain yield with significant (36.6%) reduction of N application (101 kg ha^{-1}) than previous fixed-time split N recommendation and better economic advantage for the rainfed lowland rice production in Fogera.

Reference

Ahmad N., Ahmad Z., Muhammad J, and Akhtar A. 2016. Bridging the Yield Gap in Rice Production by Using Leaf Color Chart for Nitrogen Management. Journal of Botany Volume 2016, Article ID 2728391, 6 pages http://dx.doi.org/10.1155/2016/2728391.

Bouyoucos G. J. 1951. A recalibration of the hydrometer method for making mechanical analysis of soils 1. Agronomy Journal, 43(9), 434–438. https://doi.org/10.2134/agronj1951.00021962004300090005x [Crossref], [Web of Science ®], [Google Scholar].

Chaudhary Santosh Kumar, MP Yadav, DD Yadav, Nausad Khan, DK Mahto, Sushil Kumar Yadav and Anjani Kumar Singh. 2018. Response of need based nitrogen application on growth and yield of rice (Oryza sativa L.) in irrigated transplanted condition in North India. Journal of Pharmacognosy and Phytochemistry 2018; SP1: 3268-3273.

Chittapur B.M, M.R Umesh and D.P. Biradar. 2015. Decision support tools for nitrogen nutrition in cereals. Karnataka J. Agric. Sci., 28(4): (446-453).

CSA (Central Statistical Agency). 2019. Report on area and production of major crops (private peasant holdings, meher season). The federal democratic republic of Ethiopia central statistical agency agricultural sample survey Volume I. Statistical bulletin 589, Addis Ababa, Ethiopia.

Havlin J. L., Beaton J. D., Tisdale S. L. and Nelson W. L. 1999. Function and forms of N in plants. In Soil Fertility and Fertilizers (6th ed., pp. 345. Prentice Hall. [Google Scholar].

Houshmandfar Alireza, and Anthony Kimaro. 2011. Calibrating the leaf color chart for rice nitrogen management in Northern Iran. African Journal of Agricultural Research Vol. 6(11), pp. 2627-2633, DOI: 10.5897/AJAR10.980 ISSN 1991-637X.

Iqbal Mazher Farid, Muzzammil Hussain and Muhammad Anjum Ali.2016. Integrated nitrogen management by leaf color chart technique in transplanted rice. International Journal of Advanced Research in Biological Sciences ISSN: 2348-8069 www.ijarbs.com DOI: 10.22192/ijarbs Coden: IJARQG(USA) Volume 3, Issue 12 – 2016.

Islam Zahirul, Musherraf Husain, M. Murshedul Alam, and B. Bagchi. 2007. The leaf color chart: a low-cost technology for need-based nitrogen management in rice. In: Islam Zahirul Mahabub Hossain Thelma Paris Bill Hardy Joyce Gorsuch (eds), 2007. Technologies for improving rural livelihoods in rainfed systems in South Asia. Los Baños (Philippines): International Rice Research Institute. 124 p.

Landon J.R. 1991. Booker Tropical Soil manual: A handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York, 474p

MoA (Minstry of Agriculture). 2020. National Rice Development Strategy-II, 2020 – 2030, Addis Ababa, Ethiopia. 44 pp.

Mohidem, N.A.; Hashim, N.; Shamsudin, R.; Che Man, H. 2022. Rice for Food Security: Revisiting Its Production, Diversity, Rice Milling Process and Nutrient Content. Agriculture 2022, 12, 741. https://doi.org/10.3390/agriculture12060741.

Mulugeta Seyum, Heluf Gebre kidan. 2014. Inherent Properties and Fertilizer Effects of Flooded Rice Soil. Journal Agronomy, 13(2): 72–78.

Nacjimuthu Gunasekhar, V.Velu, P. Malarvizhi, S. Ramasamy and L. Gurusamy. 2007. Standardaisation of Leaf Color Chart Based Nitrogen Management in Direct Wet Seeded Rice (*Oryza sativa* L.). Journal of Agronomy 6(2):338-343.

Reena, V.C. Dhyani, Sumit Chaturvedi and Himansu Sekhar Gouda. 2017. Growth, Yield and Nitrogen Use Efficiency in Wheat as Influenced by Leaf Colour Chart and Chlorophyll Meter Based Nitrogen Management. International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706 Volume 6 Number 12 (2017) pp. 1696-1704.

Sathiya K. and T. Ramesh. 2009. Effect of Split Application of Nitrogen on Growth and Yield of Aerobic Rice. Asian J. Exp. Sci., Vol. 23, No. 1, 2009; 303-306.

Satpute S.B., T. Das, D.T. Surje and S. K. Maity. 2015. Nitrogen management using Leaf Color chart (LCC) and nitrogen level in Kharif rice. INDIAN JOURNAL OF APPLIED RESEARCH Volume: 5 Issue :2. Feb 2015. ISSN - 2249-555X. pp 816-820.

Singh Bhupender and P. K. Sharma. 2016. Effect of nitrogen management using leaf colour chart (LCC) on growth, yield attributes and yield in transplanted rice (Oryza sativaL.). An Asian Journal of Soil Science. Volume 11 | Issue 1 | June, 2016 | 151-154 | □ e ISSN–0976–7231.

Sen Avijit, Vinod Kumar Srivastava, Manoj Kumar Singh, Ram Kumar Singh, Suneel Kumar. 2011. Leaf Colour Chart vis-a-vis Nitrogen Management in Different Rice Genotypes. American Journal of Plant Sciences, 2011, 2, 223-236 doi:10.4236/ajps.2011.22024.

Subedi P., S. K. Sah1, S. Marahatta1 and A. P. Regmi. 2017. Need based nitrogen management in hybrid and improved rice varieties under dry direct seeded condition. Journal of Agriculture and Forestry University, Volume 1 (2017)

Subedi P. and S. Panta. 2018. Some Aspects of Nitrogen Management and Its Real Time Application in Direct Seeded Rice Using Leaf Color Chart. Int. J. Appl. Sci. Biotechnol. Vol 6(2): 81-86. DOI: 10.3126/ijasbt.v6i2.20419

Sudhalakshmi C., V. Velu and T.M. Thiyagarajan. 2008. LEAF COLOUR CHART FOR NITROGEN MANAGEMENT IN RICE– A REVIEW. Agric. Rev., 29 (4) : 306 - 310, 2008

Suresh M., D. Balaguravaiah and G. Jayasree. 2017. Calibrating the Leaf Colour Chart and SPAD Based Nitrogen Management on Leaf N Content and Yield in Rice. Int. J. Pure App. Biosci. 5 (4): 1382-1387. DOI: http://dx.doi.org/10.18782/2320-7051.5527. ISSN: 2320 – 7051.

Tekalign Tadese., Haque I. and Aduayi E. A. 1991. Soil, plant, water, fertilizer, cattle manure and compost analysis manual. Plant division working document 13. ILCA, Addis Ababa. [Google Scholar].

Walkley A. and Black. I. A. 1934. An examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37(1), 29–38. https://doi.org/10.1097/00010694-193401000-00003 [Crossref], [Google Scholar].