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Calibrating leaf colour chart for nitrogen management in *Rabi* maize (*Zea mays* L.) under varied plant density

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Abstract
Many farmers are applying nitrogen fertilizer to maize in large quantities than crop requirement to obtain maximum possible yield in maize. A field experiment was conducted at the Wet land farm of Sri Venkateswara Agricultural College, Tirupati during *Rabi* season of 2017-18 to calibrate Leaf colour chart for nitrogen management under varied plant density and to establish threshold leaf colour greenness to guide in-season right quantity fertilizer N for top dressing in maize. The experiment consisted of twenty seven treatment combinations comprising of three planting densities (66,666, 83,333 and 1,11,111 plants ha^{-1}), three nitrogen levels (30, 35 and 40 kg N ha^{-1}) and three LCC threshold values (LCC 4, 4.5 and 5). Yield attributes like number of cobs plant^{-1}, cob length, cob girth, number of kernel rows cob^{-1} and number of kernels row^{-1} were significantly higher at lower planting density but, kernel yield (6004 kg ha^{-1}) was significantly maximum at higher stand density (1,11,111 plants ha^{-1}). Pertaining to nitrogen application based on leaf colour chart (LCC), maximum yield was registered at higher rate of nitrogen 40 kg N ha^{-1} by using higher LCC threshold value (LCC-5). Experimental results disclosed that, in maize N fertilizers can be managed more efficiently by supplying fertilizer nitrogen levels based on leaf colour as measured by LCC than blanket recommendation.

Keywords: Plant density, nitrogen, leaf colour chart, maize and yield

Introduction
Maize (*Zea mays* L.) in America and India is referred as corn which literarally means that “which sustains life”. Traditionally, it is one of the most important cereal crop and originated from Mexico in Central America and it belongs to the family *Gramineae* or *Poaceae*. Globally, among the cereal crops, maize is third next to wheat and rice in terms of utility and consumed as food by millions of people especially in developing countries. Maize has the highest genetic yield potential among the cereals, therefore it is called as “Queen of cereals”. Maize possess tremendous potential in terms of feed for dairy, poultry and piggery. In India one of the major limiting factors for maize cultivation is plant population. Generally, plant densities affect plant architecture, alters growth and developmental patterns, influences carbohydrate production and partition. Parallel to the increasing plant density the individual production of plants lessened but the yield per unit area increases (Muranyi, 2015) [7]. It is an established fact that higher grain yield mainly depends on optimum plant density and optimum application of fertilizer particularly nitrogen.

Demand of nitrogen fertilizer in maize is greater than that of the other nutrients because it is an exhaustive feeder. If nitrogen deficiency occurs at tasseling and silking stages it may significantly affect crop growth and yield (Shresth *et al.* 2018) [12]. If nitrogen application is not synchronized with crop demand, it results in low N-use efficiency. Major important reason for low N use efficiency is application of excess nitrogen than required with inefficient splitting. The better remedy could be to synchronize N application with crop demand. It can answer the questions of when, where and how much nitrogenous fertilizers are to be applied through synchronizing N supply with the crop demand, by following precision N management like chlorophyll meter, Green seeker and Leaf colour chart (LCC) which is less expensive for quick and non-destructive *in-situ* tools for measuring relative content of chlorophyll in leaf. LCC is an ideal tool to optimize N use, irrespective of the source of N applied *viz.*, organic manure, biologically fixed N, or chemical fertilizers (Balasubramanian *et al*., 2000) [2]. LCC proves to be an effective tool for detecting requirement of additional nitrogen in the maize for higher yields and increased profit compared with fixed nitrogen levels (Pasuquin *et al.*, 2012) [8]. The LCC has emerged as potential solution to make instant recommendation of N fertilizers as per need of the crop using threshold leaf greenness.

Therefore, plant density and N application are often considered the most critical for crop management practices to improve grain yield and N use efficiency (NUE) during intensive maize production. Hence, keeping in view of the above present field investigation was undertaken to calibrate the precision nitrogen management in *rabi* maize (*Zea mays* L.) using leaf colour chart under varied plant densities and to establish LCC threshold values for guiding need based N fertilizer application in maize.

Material and Methods

The field experiment was conducted at the Wet land farm of Sri Venkateswara Agricultural College, Tirupati (13.6°N, 79.3°E and 182.9 m above mean sea level) during *Rabi* season of 2017-18 to study the response of maize hybrid to different plant population and nitrogen levels using leaf colour chart. The experimental soil was sandy clay loam, alkaline in reaction (pH 7.9) with EC 0.14 (dSm^{-1}) at 25 ºC, low in organic carbon (0.28%), low in available nitrogen (183 kg ha^{-1}), medium in available phosphorus (25.3 kg ha^{-1}) and medium in available potash (185 kg ha^{-1}). Experiment was laid out in Split-Split plot design having three replications. The treatment comprises three planting densities (66,666, 83,333 and 1,11,111 plants ha^{-1}) as main plots, three nitrogen levels (30, 35 and 40 kg ha^{-1}) as sub plots and three LCC threshold values (LCC 4, 4.5 and 5) as sub-sub plots.

Maize crop (Hybrid-DHM-117) was sown on 16th November 2017 using three different spacings *viz.*, 75cm x 20cm, 60cm x 20cm and 45cm x 20cm. The recommended dose of 80:80 kg P_2O_5 and K_2O ha^{-1} through SSP and MOP were applied to the soil as basal along with 60 kg N ha^{-1} through urea, in all the treatments. However, remaining 180 kg urea was applied based on leaf colour chart at different splits when it falls below the LCC threshold levels at every 10 days interval from 21 days after sowing to silk emerging stage *i.e.*, 21, 31, 41, 51 and 61DAS. A 'six panel' LCC was used to match leaf colour in ten plants from each net plot. Observations were taken for 10 plants by placing the middle part of the youngest fully expanded and healthy leaf on the top of the colour strips in the chart. When six or more leaves read below a set critical value (4, 4.5 and 5), urea was applied as per the treatment. LCC readings were taken at same time of the day (8:00-11:00 AM). However, during observation LCC was not exposed directly to sunlight and leaf being measured was shielded from the sun. Based on LCC total quantity of N applied in different treatments and total quantity of N saved in each treatment combination was given in Table 1. Planting of maize at lower density required lower amount of nitrogen (157.8 kg N ha^{-1}) in which N saving was 82.2 kg N ha^{-1}. Whereas at higher plant densities total quantity of N applied and N saved was 182.6 and 87.4 kg N ha^{-1}, respectively. Among the different combinations of treatments, total amount of N was applied at higher rate (219.9 kg N ha^{-1}) to sowing of maize at higher plant densities along with application of higher rate of nitrogen using higher LCC threshold ($P_3N_3L_3$), however lower amount of N was applied (140 kg N ha^{-1}) at lower plant densities along with application of lower rate of nitrogen using lower LCC threshold ($P_1N_1L_1$) over 240 kg N ha^{-1} (recommended). Crop was grown under fully irrigated conditions and two hand weedings were done at 20 and 40 days after sowing to minimize crop- weed competition. There was no serious incidence of any insect-pest and disease during the experimental period.

Collecting the data pertaining to yield attributes and yield, five plants were randomly selected from each net plot. After physiological maturity, the crop was harvested plot-wise and cobs were dried in bright sunshine, shelled and the grains were cleaned properly. Grains were thoroughly dried plot by plot based on treatment, and their yield attributes and yield was recorded. From each unit plot grains were sun-dried to 14% moisture and weighed carefully and the plot yield was recorded in kilogram per hectare (kg ha^{-1}).

Table 1: Quantity of fertilizer N applied and saved in various treatments based on LCC

Total quantity of fertilizer N applied and saved (kg ha^{-1})							
		L_1	**L_2**	**L_3**	**Mean for each treatment combination**	**Mean N applied**	**Mean N saved**
P_1	N_{30}	140	150	160	150.0	157.8	82.2
	N_{35}	141.5	153.2	176.5	157.0		
	N_{40}	153.2	166.6	179.8	166.5		
P_2	N_{30}	160	170	180	170.0	172.6	67.4
	N_{35}	164.8	164.9	188.2	172.6		
	N_{40}	166.4	179.4	179.9	175.2		
P_3	N_{30}	160	170	190	173.3	182.6	57.4
	N_{35}	166	176.5	188.6	177.0		
	N_{40}	179.7	193.1	219.9	197.5		
Mean for L		159.0	169.3	184.7			

Results and Discussion

Early formation of reproductive structures at lower planting density (66,666 plants ha^{-1}) with less inter plant competition and ample availability of water and nutrients might have increased the grain filling period and cob size which in turn resulted in more number of average cobs $plant^{-1}$ compared to higher stand density *i.e.*, P_2 (83,333 plant ha^{-1}) and P_3 (1,11,111 plant ha^{-1}) but it was not statistically significant (Table 2). These results are in conformity with the findings of Mangal *et al.*, (2017) [6] and Revathi *et al.* (2017) [9]. Lower rate of nitrogen application N_1 (30 kg N ha^{-1}) produced less number of cobs $plant^{-1}$ as compared to other higher rate of nitrogen tried *i.e.*, N_2 (35 kg N ha^{-1}) and N_3 (40 kg N ha^{-1}). More number of cobs formed under favourable N nutrition tends to bear more number of cobs. These results corroborates the findings of Zothanmawii *et al.*, (2018) [17]. Higher cob numbers at LCC-5 (L_3), was owing to adequate supply of nitrogen at different splits at all the stages of crop growth as evidenced by the nutrient supply and responsible for rapid growth in stem, leaves and cobs. Similar results were also reported by Kumar *et al.* (2018) [4].

Table 2: Number of cobs plant^{-1} in maize as influenced by plant density, nitrogen levels and LCC threshold value

		Number of cobs plant^{-1}				
		L_1	L_2	L_3	Mean for P	Mean for N
P_1	N_{30}	1.00	1.06	1.26	1.14	1.12
	N_{35}	1.06	1.13	1.20		
	N_{40}	1.13	1.13	1.26		
P_2	N_{30}	1.06	1.06	1.20	1.13	1.13
	N_{35}	1.06	1.06	1.20		
	N_{40}	1.06	1.13	1.33		
P_3	N_{30}	1.13	1.13	1.20	1.13	1.15
	N_{35}	1.06	1.13	1.26		
	N_{40}	1.06	1.10	1.13		
Mean for L		1.07	1.10	1.23		

	SEm ±	CD (P = 0.05)
P	0.01	NS
N	0.01	NS
L	0.02	0.06
P x N	0.02	NS
P x L	0.03	NS
N x L	0.03	NS
P x N x L	0.06	NS

Number of kernel rows cob^{-1} (Table 3) did not affect significantly but it was recorded maximum at lower planting density (66, 666 plants ha^{-1}) compared to higher stand density *i.e.*, P_2 (83,333 plant ha^{-1}) and P_3 (1,11,111 plant ha^{-1}). Number of kernels row^{-1} was significantly affected by various plant densities and it recorded maximum at lower stand density. These might be due to lower planting density with adequate supply of nitrogen and might have set early sink with accumulated photosynthates due to early formation of reproductive structures which was evident from the advancement of silking might have been responsible for cobs with more number of rows. These results are in tune with the findings reported by Revathi *et al.* (2017) [9]. Lower rate of nitrogen application N_1 (30 kg N ha^{-1}) produced less number of kernel rows cob^{-1} as compared to other higher rate of nitrogen tried *i.e.*, N_2 (35 kg N ha^{-1}) and N_3 (40 kg N ha^{-1}). Higher accumulation of dry matter in plant due to higher N applied and effective translocation of photosynthates from source to sink might have further improved number of rows cob^{-1}. Similar trend of findings were reported by Iqbal *et al.*, (2016) [3] and Sharifi and Namvar (2016) [11]. Also maximum number of kernel rows cob^{-1} was obtained with higher threshold LCC-5 (L_3), than in LCC-4.5 (L_2) and LCC-4 (L_1). Supply of optimum rate of nitrogen at different splits based on higher LCC threshold-5 may caused higher kernel rows cob^{-1}. Similar result was also reported by Kumar *et al.*, (2018) [4] and Selvakumar *et al.* (2017) [10]. Interaction of plant density and leaf colour chart threshold exerted significant influence during the experiment, while other interactions were not statistically traceable. Whereas, maximum number of kernel rows cob^{-1} and number of kernels row^{-1} were recorded at the combination of P_1L_3 (16.1 and 30.1), respectively and it was statistically superior than other combinations (Table 4).

Table 3: Number of kernel rows per cob and number of kernels per row of maize as influenced by plant density, nitrogen levels and LCC threshold value

		Number of rows cob^{-1}					Number of kernels row^{-1}				
		L_1	L_2	L_3	Mean for P	Mean for N	L_1	L_2	L_3	Mean for P	Mean for N
P_1	N_{30}	14.4	15.1	15.8	15.5	15.1	26.6	26.8	28.8	28.3	26.2
	N_{35}	14.8	15.4	16.0			28.5	25.8	29.4		
	N_{40}	15.6	15.6	16.1			27.2	29.2	32.2		
P_2	N_{30}	14.6	14.8	16.0	15.4	15.4	25.4	25.8	29.2	27.2	26.5
	N_{35}	14.8	15.6	16.1			25.8	26.4	26.4		
	N_{40}	15.5	15.8	16.1			27.0	27.7	31.5		
P_3	N_{30}	14.4	15.0	15.4	15.2	15.6	22.6	24.8	26.2	25.2	28.0
	N_{35}	15.0	15.0	15.6			24.6	25.4	26.1		
	N_{40}	15.1	15.2	15.6			25.4	25.8	26.0		
Mean for L		15.0	15.4	15.6			25.7	27.2	27.8		

	Number of rows cob^{-1}		Number of kernels row^{-1}	
	SEm ±	CD (P = 0.05)	SEm ±	CD (P = 0.05)
P	0.14	NS	0.17	0.68
N	0.09	0.29	0.23	0.70
L	0.10	0.29	0.20	0.59
P x N	0.16	NS	0.39	NS
P x L	0.17	0.50	0.35	1.01
N x L	0.17	NS	0.35	NS
P x N x L	0.30	NS	0.61	1.76

The data suggested that maximum cob length and cob girth of maize (Table 5) was found at lower plant density P_1 (66,666 plants ha^{-1}) than other plant densities *viz.*, P_2 (83,333 plants ha^{-1}) and P_3 (1, 11,111 plants ha^{-1}). This might be due to fact that each individual plant in the community had the advantage of utilizing all the growth resources due to lack of competition, resulting in accumulation of higher level of assimilates, which might have manifested the formation of higher cob length. Mangal *et al.*, (2017) [6] and Zeleke *et al.*, (2018) [16] also stated similar results.

Table 4: Number of rows cob^{-1} and number of kernels row^{-1}as influenced by interaction of plant density and leaf colour chart

Number of rows cob^{-1}					Number of kernels row^{-1}			
	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
P_1	15.0	15.4	16.1	15.5	26.5	28.2	30.1	28.3
P_2	15.0	15.4	15.8	15.4	26.4	27.6	27.8	27.2
P_3	14.9	15.5	15.0	15.2	24.4	25.8	25.4	25.2
Mean	15.0	15.4	15.6		25.7	27.2	27.8	
SEm ±		0.1			SEm ±		0.3	
CD (P = 0.05)		0.4			CD (P = 0.05)		1.0	

Cob length and cob girth was significantly maximum with application of higher level of nitrogen N_3 (40 kg N ha^{-1}) at different splits compared to lower levels. Better crop growth coupled with early tasseling and silking, enabled the crop to have more number of days for accumulating the assimilates to sink through longer period of translocation would have resulted in higher cob length. The results as evidenced in the present study are in conformity with the findings of Ahmed *et al.* (2018) [1] and Zothanmawii *et al.*, (2018) [17]. Higher length of cob and cob girth noticed at higher threshold of LCC-5 (L_3), than in LCC-4.5 (L_2) and LCC-4 (L_1) may be attributed to better crop performance as expressed by superiority of plant height, number of green leaves per plant, higher leaf area and LAI, and higher dry matter production and its accumulation. These results are in conformity with the findings of Veer *et al.* (2016) [14]. Interaction of plant density, nitrogen levels and leaf colour chart threshold exerted was significant on cob length during the experiment, while other interactions were not statistically traceable. Whereas, maximum cob length were recorded at the combination of 66,666 plants ha^{-1} with LCC-5 (15.5 cm) and at application of 40 kg N ha^{-1} based on LCC-5 (15.4), respectively and it was statistically superior to all the other combinations (Table 6).

Scrutiny of data pertaining to kernel yield disclosed that each successive increase in plant density from lower level 66,666 plants ha^{-1} (P_1) to higher level 1, 11,111 plants ha^{-1} (P_3) resulted in higher kernel yield during field investigation (Table 7). However, lower kernel yield was obtained from 66,666 plants ha^{-1} (P_1) which might be due to better yield attributes at lower populations and not able to compensate the decrease in the yield due to reduced population, resulting in lower grain yields at lower population. This decreasing trend with increase in plant density was also reported by Yan *et al.* (2017) [15]. Perusal of data on kernel yield of maize revealed that with increasing levels of nitrogen upto 40 kg N ha^{-1} (N_3) kernel yield was also increased. Kernel yield of maize is the result of simple product of yield attributes and plant population, which in the present case were significantly and favourably influenced by the application of comfortable level of nitrogen at different splits. Further, nitrogen nutrition might have improved source-sink relationship, with better translocation of photosynthates for grain formation. These results corroborate the findings of Iqbal *et al.*, (2016) [3] and Kwadzo *et al.* (2016) [5].

Table 5: Cob length and cob girth of maize as influenced by plant density, nitrogen levels and LCC threshold value

		Cob length (cm)					Cob girth (cm)				
		L_1	L_2	L_3	Mean for P	Mean for N	L_1	L_2	L_3	Mean for P	Mean for N
P_1	N_{30}	14.2	14.7	15.1	15.2	14.6	15.8	16.5	16.7	16.9	16.2
	N_{35}	14.8	15.5	15.7			16.5	16.6	16.8		
	N_{40}	15.4	15.6	15.9			17.0	17.6	18.3		
P_2	N_{30}	14.4	14.6	13.7	14.8	14.8	16.1	16.1	16.5	16.4	16.3
	N_{35}	14.7	14.7	15.3			16.1	16.3	16.7		
	N_{40}	15.6	14.9	15.5			16.1	16.5	17.3		
P_3	N_{30}	13.4	14.5	14.8	14.6	15.2	15.7	16.2	16.3	16.3	17.0
	N_{35}	14.4	14.5	14.8			15.6	15.9	16.5		
	N_{40}	15.0	14.9	15.0			16.3	16.9	17.3		
Mean for L		14.7	14.9	15.1			16.2	16.5	16.8		

	Cob length (cm)		Cob girth (cm)	
	SEm ±	CD (P = 0.05)	SEm ±	CD (P = 0.05)
P	0.10	0.40	0.05	0.18
N	0.11	0.32	0.15	0.45
L	0.09	0.26	0.11	0.31
P x N	0.18	0.56	0.25	NS
P x L	0.16	NS	0.19	NS
N x L	0.16	0.46	0.19	NS
P x N x L	0.28	NS	0.33	NS

Maximum kernel yield was recorded with higher threshold LCC-5 (L_3), than in LCC-4.5 (L_2) and LCC-4 (L_1). Supply of nitrogen at higher LCC threshold-5 evidenced by the higher nutrient supply from source to sink is responsible for higher kernel yield. Application of nitrogen at LCC 5 (L_3) matched the crop demand at different physiological stages and reduced the losses through denitrification, volatilization by applying nitrogen in more number of splits that resulted in highest grain yield.

Table 6: Length of maize cob as influenced by interaction of plant density, nitrogen levels and threshold values of leaf colour chart

Plant density and nitrogen levels					Nitrogen levels and leaf colour chart				
	N_{30}	N_{35}	N_{40}	Mean		L_1	L_2	L_3	Mean
P_1	14.6	15.4	15.5	15.2	N_{30}	14.1	14.7	15.1	14.6
P_2	14.9	14.3	15.3	14.8	N_{35}	14.7	14.9	14.7	14.8
P_3	14.3	14.6	14.9	14.6	N_{40}	15.1	15.1	15.4	15.2
Mean	14.6	14.8	15.2		Mean	14.6	14.9	15.1	
SEm ±	0.1					SEm ±		0.15	
CD (P = 0.05)	0.5					CD (P = 0.05)		0.45	

Lower kernel yield was found at application of nitrogen based on threshold LCC-4 may be attributed to stress of nitrogen at all the stages of growth leading to detrimental effect on growth, yield components and yield. These findings are in line with those of Pasuquin *et al.* (2012) [8] and Singh *et al.* (2014) [13].

Interaction of plant density and nitrogen levels exerted significant influence on grain yield during the experiment, while other interactions were not statistically traceable. Whereas, maximum grain yield was recorded at a combination of higher plant densities using LCC-5 (6579 kg ha^{-1}) and it was statistically superior over other combinations (Table 8).

Conclusion

The experimental results disclosed that application of N based on LCC gadget is a perfect strategy that always gave advantage of either N fertilizer saving, resulted in higher yield with less amount of nitrogen there by reducing the cost of cultivation. It was further concluded that need based application of 40 kg N ha^{-1}, whenever leaf greenness is less than LCC threshold value 5 is the appropriate fertilizer N management strategy along with a basal dose of 60 kg N ha^{-1}. The recommendation of LCC threshold value-5, below which crop may suffer from N deficiency resulting in yield loss.

Table 7: Kernel yield of maize as influenced by plant density, nitrogen levels and LCC threshold value

		Kernel yield (kg ha^{-1})				
		L_1	L_2	L_3	Mean for P	Mean for N
P_1	N_{30}	4043	4079	4425	4402	4871
	N_{35}	4135	4376	4609		
	N_{40}	4546	4608	4793		
P_2	N_{30}	4588	4762	5370	5119	5158
	N_{35}	4623	5069	5488		
	N_{40}	4984	5492	5695		
P_3	N_{30}	5219	5334	5862	6004	5496
	N_{35}	5337	6014	6530		
	N_{40}	5844	6529	7365		
Mean for L		4813	5140	5571		

	SEm ±	CD (P = 0.05)
P	49	192
N	67	208
L	71	203
P x N	117	360
P x L	123	NS
N x L	123	NS
P x N x L	212	NS

Table 8: Kernel yield (kg ha^{-1}) of maize as influenced by interaction of plant density and nitrogen levels

Plant density and nitrogen levels				
	N_{30}	**N_{35}**	**N_{40}**	**Mean**
P_1	4183	4373	4649	4402
P_2	4958	5141	5258	5119
P_3	5472	5961	6579	6004
Mean	4871	5158	5496	
SEm ±		117		
CD (P = 0.05)		360		

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