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# Study on nutrient management of hybrid maize (*Zea mays* L) through decision support tools

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**Abstract**
A field study was conducted during *Kharif* 2019-20 at Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Telangana, India to study the nutrient management in hybrid maize (*Zea mays* L.) using simple hand-held decision support tools *viz*., LCC, SPAD and Green seeker. Treatments consisted of state recommended nitrogen @ 200 kg ha$^{-1}$ in three splits, Leaf Colour Chart (LCC) based N application at threshold 3 and 4, SPAD chlorophyll meter based N application at threshold 35 and 40 and Green Seeker based N application at NDVI value 0.6 and 0.8 compared with absolute control and RDN. The field experiment was conducted in Randomized complete block design with three replications. The results of the field study revealed that application of nitrogen-based on Green Seeker NDVI at threshold 0.8 recorded significantly higher maize grain (8408 kg ha$^{-1}$), and stover (9923 kg ha$^{-1}$)yields with higher N uptake of 225.5 kg ha$^{-1}$ .Further, among different precision nitrogen management practices, significantly higher Partial Factor Productivity (57.8 kg kg$^{-1}$), Recovery Efficiency (99.7%), Agronomic Efficiency (25.7 kg kg$^{-1}$) were obtained in nitrogen management through SPAD based N at threshold 40 as compared to recommended dose of nitrogen and absolute control.

**Keywords:** Decision support tools, precision nitrogen management, maize, nitrogen use efficiencies

## Introduction
Maize (*Zea mays* L) is one of the major cereal crops with wide adaptability to diverse agro-climatic conditions and stands first in production, in the world. In India, it ranks third after rice and wheat. Maize is being called "Queen of cereals" due to its higher production potential and wider adaptability. It requires a balanced nutrients supply (N, P and K). Maize being an exhaustive crop, the hybrids of maize are highly responsive to fertilization. When N application is not synchronized with crop demand, N losses from the soil plant system are large leading to low N fertilizer use efficiency. There is a need to synchronize time of N fertilizer application with high crop nutrient demand to optimize nutrient use and minimize environmental pollution. Farmers generally use leaf colour as a visual and subjective indicator for N fertilizer application (Furuya, 1987) [9]. Generally farmers apply high doses of N fertilizer to maintain dark green foliage leading over application of fertilizers N and low recovery efficiency. Thus, the spectral properties of leaves should be used in a rational manner to guide need-based fertilizer N applications. Further, in recent years many precision tools are being used in the nitrogen management, especially in maize. Among these precision tools like, leaf colour chart (LCC) is one and it was developed for rice and it is also suitable for maize as indicated by spectral reflectance measurement performance on rice (Balasubramanian *et al*., 1999 and Balasubramanian *et al*., 2000) [2, 3] and maize leaves (Witt *et al*., 2005) [21]. LCC helps in promoting need based variable N application based on soil N-supply and crop demand. The SPAD chlorophyll meter is used to diagnose the N status in crops and determine the right time of N application (Mohanty *et al*., 2016) [15]. The application of optical sensors in agriculture has advanced rapidly in the recent years. The Green seeker optical sensor works on reflection of light from the chlorophyll, similarly these sensors use visible and near-infrared (NIR) spectral radiation from plant canopies to detect N stress and crop vigour (NDVI) values are used as the basis for nitrogen application. NDVI measurements can range from -1 to +1, with higher values indicating better plant health. It has the ability to predict yield potential of crops (Harrell *et al*., 2011). Hence, thus experiment was conducted with an objective to find out optimum threshold level of LCC, SPAD and NDVI for N application for hybrid maize with improved nutrient efficiency indices.

## Materials and methods
A field trial was carried out at the main farm, Agricultural Research Station, Rajendranagar (17.19'N and 78.23'E) Hyderabad during *Kharif* 2019-20 with an objective to know the

performance of hybrid maize with higher nutrient efficiency under different nitrogen management practices through decision support tools. The experiment was laid out in Randomized Complete Block Design consisted of eight treatments with three replications. The soil of the experimental site was sandy loam with pH 7.46 and low in electrical conductivity (0.26 dS $m^{-1}$) and organic carbon content (0.45) and low in available N (238.4 kg $ha^{-1}$), high in available phosphorus (80.4 kg $P_2O_5$ $ha^{-1}$) and available potassium (343.1 kg $K_2O$ $ha^{-1}$). The hybrid maize DHM-117 used in the investigation and seeds were dibbled at 60 cm x 20 cm spacing. There are eight treatments consisted of state recommended nitrogen (RDN) @ 200 kg $ha^{-1}$ in three splits, LCC based N application at threshold 3 and 4, SPAD based N application at threshold 35 and 40 and Green Seeker based N application at NDVI value 0.6 and 0.8 compared with absolute control and RDN (200 kg $ha^{-1}$). Pre-requisite quantity of fertilizer dose was applied as per treatments. Recommended dose of 60 kg $P_2O_5$ $ha^{-1}$ & 50 kg $K_2O$ $ha^{-1}$ in the form SSP and MOP and 35 per cent RDN (except control) through Urea were applied as basal application for all the treatments. Remaining nitrogen was applied in the remaining treatments *viz.*, in $T_2$, $T_3$, $T_4$, $T_5$, $T_6$ & $T_7$ in three replications as per the crop demand from time to time according to LCC / SPAD /Green Seeker readings. The details of amount of N applied for individual treatments and total quantity is given in Table 1.

**Table 1:** Quantity of nitrogen (kg $ha^{-1}$) applied based on LCC, SPAD and Green Seeker values:

| Treatments | Basal | 14 DAS | 21 DAS | 28 DAS | 35 DAS | 42 DAS | 49 DAS | 56 DAS | 63 DAS | No. of splits | Total N applied (kg $ha^{-1}$) | Saving in N fertilizer over RDF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1 | 66.6 | - | - | - | 66.6 | - | - | 66.6 | | 3 | 200 | 0 |
| T2 | 70 | - | - | | 32.5 | - | - | 32.5 | - | 3 | 135 | 65 |
| T3 | 70 | | | 32.5 | | - | 32.5 | - | - | 3 | 135 | 65 |
| T4 | 70 | - | - | - | 32.5 | | | 32.5 | - | 3 | 135 | 65 |
| T5 | 70 | - | - | 32.5 | - | - | 32.5 | - | - | 3 | 135 | 65 |
| T6 | 70 | 32.5 | - | 32.5 | 10 | - | - | - | - | 4 | 145 | 55 |
| T7 | 70 | 32.5 | - | 32.5 | 10 | 10 | 10 | - | - | 6 | 165 | 35 |
| T8 | - | - | - | - | - | - | - | - | - | 0 | 0 | 0 |

T1-RDN (200 kg $ha^{-1}$ in three equal splits), T2- LCC based N application at threshold 3, T3- LCC based N application at threshold 4, T4- SPAD based N application at threshold 35, T5- SPAD based N application at threshold 40, T6-Green seeker based N application at NDVI value 0.6, T7-Green seeker based N application at NDVI value 0.8, T8- Absolute control (no nitrogen) only $P_2O_5$ and $K_2O$ as basal.

Immediately after sowing Atrazine 50 per cent WP @ 1.5 kg a.i $ha^{-1}$ was sprayed to control weeds followed by two hand weedings at 25 and 45 days after sowing. During the season earthing up was carried out at 30 days after sowing. Plant population was maintained in all the treatments by thinning out of excess seedlings at 12 DAS and leaving one seedlings per spot. Healthy crop stand was ensured by adopting need based crop protection and recommended packages of practices. Five plants were selected at random and tagged. These plants were used for recording growth parameters, yield attributes and yield. N uptake was determined by multiplying dry mater accumulation at harvest by respective percentage of N content in plant and grain samples and transformed into kg $ha^{-1}$. Different nutrient use efficiencies were calculated using following formulae given by Cassman *et al.*, (1998) [5].

$$PFP_N = \frac{\text{Grain yield kg ha}^{-1}}{\text{Nitrogen applied kg ha}^{-1}}$$

$$AE_N(\%) = \frac{\text{Grain yield in "N" fertilized plot - Control plot}}{\text{Quantity of N fertilizer applied}}$$

$$RE_N(\%) = \frac{\text{[Total N uptake in "N" fertilized plot] - [Total N uptake in Control N plot) x 100}}{\text{Quantity of N fertilizer applied in N-fertilized plot}}$$

$$PNB_N = \frac{\text{Total nutrient uptake (grain + stover kg ha}^{-1})}{\text{Total amount of nutrient applied kg ha}^{-1}}$$

Where,

$PFP_N$-Partial Factor Productivity (kg grain $kg^{-1}$ N)
$AE_N$ - Agronomic efficiency (kg grain $kg^{-1}$ N)
$RE_N$ (%) - Recovery efficiency
$PNB_N$ - Partial Nutrient balance (kg nutrient uptake kg nutrient $applied^{-1}$)
N uptake was the total N uptake in grain and stover.

All the data were statistically analyzed by using standard procedure (Gomez and Gomez, 1984) and results are presented and discussed at a probability level of 5 per cent.

**Results and Discussion:**

Among the different nutrient management practices, significantly higher grain yield (8408 kg $ha^{-1}$) was recorded with $T_7$ {Green Seeker based NDVI at 0.8 (35% RDN as basal and Green seeker based N at weekly intervals after 14 DAS)} which was on par with $T_5$ {SPAD based N at threshold 40 (35% RDN as basal and SPAD based N at weekly intervals after 14 DAS)} and $T_6$ (Green Seeker based NDVI at 0.6 (35% RDN as basal and Green seeker based N at weekly intervals after 14 DAS). While lowest grain yield (4343 kg $ha^{-1}$) was recorded with $T_8$ (Control) which was significantly inferior to all other treatments. A significantly higher amount of maize stover yield (9923 kg $ha^{-1}$) was registered under N application at Green Seeker NDVI value at threshold 0.8 and significantly lower was recorded under without nitrogen fertilizer application (6073 kg $ha^{-1}$) (Table 2). The higher grain and stover yields obtained when N was managed at Green Seeker NDVI threshold 0.8 was obviously due to favourable nutrition or a balanced level of nutrient application during the crop growth stages meeting the crop requirement. It is obvious that nitrogen as a major nutrient can influence leaf N and chlorophyll content and thus consequently SPAD and NDVI values, ultimately in the final yield (Veerendra *et al.*, 2017).

Similarly, the application of nitrogen through Green Seeker based N at NDVI threshold 0.8 recorded significantly higher N uptake at harvest (225.5 kg $ha^{-1}$), which was followed by SPAD based N application at threshold 40 (211.2 kg $ha^{-1}$) as compared to RDN (159.7 kg ha$^{-1}$). Whereas, absolute control recorded significantly lower nitrogen uptake compare to other treatments (Table 3). This might be due to synchrony between N demand and supply from soil and fertilizer was probably the cause of increased uptake of N (Dobermann *et al*., 2002) [6]. This might be due to the ready availability of nitrogen for the crop that helped in enhanced absorption of phosphorous and potassium. The results are in agreement with Ravi *et al*. (2007).

**Nutrient use efficiency indices**

The effect of precision nitrogen management through decision support tools on nutrient use efficiency indices like Partial factor productivity, Agronomic Efficiency, Recovery efficiency & and Partial nutrient balance of nitrogen in hybrid maize were discussed and presented in Table 3.

**Partial factor productivity (kg grain kg$^{-1}$ N applied)**

Significantly higher Partial factor productivity (57.8 kg grain kg$^{-1}$ N applied) was registered with T5 {SPAD based N at threshold N (35% RDN as basal and SPAD based N at weekly intervals after 14 DAS)} followed by T3 (54.8 kg grain kg$^{-1}$ N applied) compared to rest of the treatments. While the lowest (36.8 kg grain kg$^{-1}$ N applied) was recorded with T1 {200 kg N ha$^{-1}$ in 3 splits 33% each at Basal, Knee high (30 DAS) and Tasseling stages (60 DAS). The trend followed the path T5>T3>T6>T4>T7>T2>T1 and relatively lower $PFP_N$ was recorded in T1 {200 kg N ha$^{-1}$ in 3 splits 33% each at Basal, Knee high (30 DAS) and Tasseling stages (60 DAS)} than treatments imposed based on LCC, SPAD and Green Seeker. The decreased $PFP_N$ with increasing amounts of N applied can be attributed to relatively less improvement in tonnage in presence of higher nutrient supplementation beyond a certain level as generally observed in all nutrients (law of diminishing returns) (Block and Hergert, 1991) [4]. This increase in NUE was mainly due to reduced N application in split doses according to crop demand, in turn, reduces the losses of N by various means. This was in accordance with Maiti *et al*. (2004) [14] and Ghosh *et al*. (2013) [10] in rice. No nitrogen use efficiency was observed under absolute control. Similar results of lower efficiencies were observed by Singh *et al*. (2002) [18], due to more N losses from the soil-plant system leading to low NUE, when N application is not synchronized with crop demand. Premalatha (2017) [17] also reported that NUE decreases with an increase in the amount of N applied and also depends on the time of N application. Similar findings were reported by Kumara *et al*. (2014) [13], Ali *et al*. (2015) [1] and Houshmandfar and Kimaro (2011) [12].

**Agronomic efficiency (kg increase in grain yield kg$^{-1}$ N applied)**

Agronomic efficiency is a product of nutrient recovery from mineral or organic fertilizer (RE) and the efficiency with which the plant uses each additional unit of nutrient (PE). It depends on management practices that affect RE and PE. Significantly higher agronomic efficiency (25.7 kg grain kg$^{-1}$ N applied) was registered with T5 {SPAD based N at threshold 40 (35% RDN as basal and SPAD based N at weekly intervals after 14 DAS)} which was on par with T7 and T6 (25.4 & 23.7 kg grain kg$^{-1}$ N applied) and the lowest (15.1 kg grain kg$^{-1}$ N applied) was recorded with T1 (RDN). Better timing and splitting of fertilizer N applications during the season was probably the major reason for the increase in agronomic N-use efficiency. N losses from the soil-plant system are large in T1, leading to low AEN when N application is not synchronized with crop demand (Peng *et al*., 1996) [16]. Similar findings were reported by Kumara *et al*. (2014) [13].

**Recovery efficiency (% of increase in N uptake kg$^{-1}$ N applied)**

Achievable level of recovery efficiency was registered in T5 {SPAD based nitrogen application at threshold 40} (99.7%) over other treatments and it as on par with T3 i.e. LCC based N at threshold 4 and T7 {Green Seeker based N at NDVI threshold 0.8} (94 and 90.3%, respectively) and the lowest recovery efficiency was noticed with T1 *i.e.,* RDN (41.1%).

Increased level of RE depends on crop demand for N, the supply of N from indigenous sources, fertilizer rate, timing product and mode of application. Recovery efficiency depends on the congruence between plant demand and nutrient release from fertilizer and is affected by the application method (amount, timing, placement and N form) and factors that determine the size of the crop nutrient sink (genotype, climate, plant density, abiotic/biotic stresses). Similar findings were reported by Tauseef *et al*. 2014) [19], Kumara *et al*. (2014) [13] in rice, Varinderpal *et al*. (2011) [20] in maize, and Ghosh *et al*. (2017) [11] in wheat.

**Partial Nutrient Balance (kg nutrient uptake kg nutrient applied $^{-1}$)**

It was observed that the highest partial nutrient balance (1.6 kg nutrient uptake kg nutrient applied -1 ) was recorded with T5 {SPAD based N at threshold 40 (35% RDN asbasal and SPAD based N at weekly intervals after 14 DAS)} which was found to be on par with T3 and T7 (1.5 & 1.4 kg nutrient uptake kg nutrient applied -1 ). T1 treatment recorded the lowest (0.8 kg nutrient uptake kg nutrient applied.

**Table 2:** Quantity of N (kg ha$^{-1}$) applied, grain and stover yields and total N uptake in hybrid maize as influenced by N management through decision support tools.

| Treatments | N applied (kg ha$^{-1}$) | Grain yield (kg ha$^{-1}$) | Stover yield (kg ha$^{-1}$) | Total N Uptake (kg ha$^{-1}$) |
|---|---|---|---|---|
| $T_1$- State recommended N (200 kg N ha$^{-1}$ in 3 splits) | 200 | 7361 | 9015 | 159.7 |
| $T_2$- LCC based N application at threshold 3 | 135 | 7020 | 8761 | 155.6 |
| $T_3$- LCC based N at threshold 4 | 135 | 7401 | 9069 | 203.6 |
| $T_4$- SPAD based N at threshold 35 | 135 | 7051 | 8518 | 172.3 |
| $T_5$- SPAD based N at threshold 40 | 135 | 7809 | 9386 | 211.2 |
| $T_6$-Green Seeker based NDVI at 0.6 | 145 | 7783 | 9419 | 201.5 |
| $T_7$- Green Seeker based NDVI at 0.8 | 165 | 8408 | 9923 | 225.5 |
| $T_8$- Control (without N application) only P & K | 0 | 4343 | 6073 | 76.5 |
| SE(m) ± | | 1007 | 375 | 4.5 |
| CD (p=0.05) | -- | 329 | 122 | 13.7 |
| CV (%) | -- | 8.1 | 2.4 | 4.4 |

**Table 3:** Nutrient use efficiency indices as influenced by precision nitrogen management through decision support tools in maize.

| Treatments | $PFP_N$ | $AE_N$ | $RE_N$ | PNB |
|---|---|---|---|---|
| | kg grain $kg^{-1}$ N applied | kg increase in grain yield $kg^{-1}$ N applied | % of increase in N uptake $kg^{-1}$ N applied | kg nutrient uptake per kg nutrient applied |
| $T_1$- State recommended N (200 kg N $ha^{-1}$ in 3 splits) | 36.8 | 15.1 | 41.1 | 0.8 |
| $T_2$- LCC based N application at threshold 3 | 51.9 | 19.8 | 58.6 | 1.1 |
| $T_3$- LCC based N at threshold 4 | 54.8 | 22.6 | 94.1 | 1.5 |
| $T_4$- SPAD based N at threshold 35 | 52.2 | 20 | 76.1 | 1.2 |
| $T_5$- SPAD based N at threshold 40 | 57.8 | 25.7 | 99.7 | 1.6 |
| $T_6$-Green Seeker based NDVI at 0.6 | 53.7 | 23.7 | 86.2 | 1.3 |
| $T_7$- Green Seeker based NDVI at 0.8 | 50.9 | 25.4 | 90.3 | 1.4 |
| $T_8$- Control (without N application) only P & K | 0 | 0 | 0 | 0 |
| SE(m) ± | 2.3 | 2.3 | 3.4 | 0.03 |
| CD (p=0.05) | 7.1 | 7.0 | 10.4 | 0.09 |
| CV (%) | 8.9 | 20.8 | 8.7 | 5.0 |

## Conclusion
From the study, it can be concluded that nitrogen management through SPAD based N at threshold 40, Green Seeker based N at NDVI 0.8 and LCC based N at threshold 4 are the best precision nitrogen management practices in hybrid maize for achieving higher nitrogen use efficiency indices.

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