

## Nitrogen application based on decision support tools to enhance productivity, nutrient-use efficiency and quality of sweet corn (*Zea mays*)

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### ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2014 and 2015 at Raichur, Karnataka, to establish optimum thresholds of leaf colour chart (LCC), chlorophyll meter (SPAD) and normalized differential vegetation index (NDVI) to guide in-season crop need-based N fertilizer application. Treatment consisted of LCC thresholds 4 and 5, SPAD 40 and 50, NDVI thresholds 0.6 and 0.8 with 30 kg/ha N whenever N level fell below threshold, blanket N (150 kg N/ha) either 2 or 3 splits, half recommended dose of nitrogen (RDN) basal + half to foliage as 2% urea at 30, 45 and 60 days after planting (DAP), and control (without N). Results revealed that LCC 5, SPAD 50 and NDVI 0.8 corresponding to 120 kg N/ha recorded higher sweet corn yield with or without husk cob, fresh grain quality and nutrient uptake over blanket 150 kg N/ha at fixed intervals. These decision support tools based N management helped to save N fertilizer 20 to 40 kg/ha besides improving agronomic efficiency of N.

**Key words :** Agronomic efficiency, Light interception, N decision support tool, Sweet corn yield

Nitrogen, an important nutrient, is responsible to a great extent for the large yield obtained under high-input agriculture. The supply of N enhances biomass production and increases yield, while its deficiency results in significant reduction in fresh cob yield, yield attributes, and economics of sweet corn (Sahoo and Mahapatra, 2007). Nevertheless, effective management of N fertilizers is a major challenge for researchers and producers to enhance yield. Many new decision support systems revealed positive relationship between N supply and yield (Moges *et al.*, 2007; Umesh *et al.*, 2014). Ideally, these techniques need to be fast and inexpensive and should allow for on-the-spot decision making. The International Rice Research Institute (IRRI), Philippines has developed a simple and inexpensive LCC that can be used as a complementary decision-making tool to determine the need for N application. The LCC evaluates N status of crops, cost effectively, avoiding leaf sampling, laboratory analysis and time lapse in receiving the results. Leaf colour chart has been used successfully to guide fertilizer N application in maize (Singh *et al.*, 2011).

Chlorophyll meter (SPAD) is a simple, quick and non-destructive *in-situ* tool for measuring relative content of chlorophyll in leaf that is directly proportional to leaf N content. The SPAD meter measures how much of the light of a certain wavelength is absorbed by the chlorophyll molecules. The instrument measures transmission of red light at 650 nm, at which chlorophyll absorbs light, and transmission of infrared light at 940 nm, at which no absorption occurs. Chlorophyll meters are faster than tissue testing for N and can help to find when plant needs N most (Ladha *et al.*, 2005). Likewise, the normalized differential vegetative index (NDVI) as measured by an optical sensor is based on the reflectance at red and near-infrared (NIR) regions and has the ability to predict yield potential of maize (Teal *et al.*, 2006). Threshold values of these decision-support tools is defined as the LCC, SPAD, NDVI readings corresponding to a leaf greenness below which the crop suffers from N deficiency resulting in yield loss. Leaf greenness can be influenced by a number of factors (e.g. hybrid, stage of growth, and some nutrients), but soil-N availability probably has the greatest effect within a field (Blackmer and Schepers, 1995).

For better N economy the traditional fixed-date variable rate strategy needs to be modified to allow the application of N across a wider seasonal range wherein above tools appear handy. A known dose per top-dressing and main-

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taining the leaf greenness up to certain threshold would hold promise. Consequently, agronomic efficiency of N would also be higher in the SPAD and LCC based N supply with considerable saving of fertilizer N. Therefore present study was undertaken with an objective to standardize LCC, SPAD and NDVI thresholds for N application for sweet corn.

## MATERIALS AND METHODS

The study was conducted at the Main Agricultural Research Station, Raichur (16.6° N, 77.3° E, 329.6 m above mean sea-level), University of Agricultural Sciences, Karnataka, during the winter (*rabi*) seasons of 2014 and 2015 on clay loam soil, having soil pH 7.76 and 280, 39.51 and 225 kg/ha available N, P<sub>2</sub>O<sub>5</sub> and available K<sub>2</sub>O respectively. The climate is subtropical, semi-arid with average annual rainfall of 690 mm. The experiment comprised 11 treatments, viz. N @ 150 kg/ha recommended dose of nitrogen (RDN) in 2 and 3 splits, N application based on leaf colour chart (LCC) threshold 4 and 5, chlorophyll meter (SPAD) threshold at 40 and 50, and GreenSeeker-based normalized differential vegetation index (NDVI) values at 0.6 and 0.8, RDN 50% basal + 50% through foliage as 2% urea thrice at each 15 days intervals up to 60 days after sowing (DAS), and control without N. It was laid out in a randomized complete-block design with 3 replications. Recommended dose of 75 kg P<sub>2</sub>O<sub>5</sub>/ha and 37.5 kg K<sub>2</sub>O/ha were applied through single superphosphate and muriate of potash at the time of sowing. The seeds of hybrid 'Sweet 75' was dibbled up to 4 to 5 cm deep at a spacing of 60 cm × 20 cm in the month of November, and all the cultural practices were followed as per package of practices.

Irrigations were given during dry spells to ensure adequate soil moisture throughout the crop season. Weeds, pests and diseases were controlled by proper prophylactic measures. Fresh cobs were harvested at milk stage. Thereafter, the crop was harvested for green fodder. Kernel and straw N and crude protein contents were analyzed by standard methods. Leaf colour chart with 6 green shades was used in this study. The third fully-expanded leaf from top of sweet corn was selected for leaf-colour measurement. Selected leaf was placed on the LCC and the colour of the middle part of the leaf was matched with greenness of the panels on the LCC. It was continuous throughout the season recorded by same person to avoid errors. The chlorophyll meter used was the hand-held Minolta SPAD-502. The SPAD values were recorded by inserting the middle portion of the index leaf in the slit of SPAD meter. From each plot, readings from 10 random plants were averaged. Optical sensor readings were taken with a hand-held GreenSeeker. The sensor was passed over the crop at a

height of about 1 m and readings with all the 3 gadgets were recorded at 15 days intervals from 15 days after planting.

Radiation interception was calculated by using the relationship  $F = (1 - I_t/I_0)$  where F is the fractional amount of radiation interception. It is the measured incident PAR on the surface of the ground (FAO Irrigation and Drainage Paper No. 56), and I<sub>0</sub> is the radiant flux density on top of the canopy. Both I<sub>t</sub>, I<sub>0</sub> and leaf-area index (LAI) were measured by using SunScan Canopy analyzer (Delta-T, Ltd. Cambridge, UK). All measurements were recorded at 11:00 to 14:00 h in a clear sunny day at intervals of 15–17 days, from 15 days after planting depending on weather conditions. The weather data were collected from an automatic Weather Station near the experimental field (Table 1).

Dry-matter accumulation was determined from 5 plants taken at the main phenological stages (six-leaf stage, knee-high stage, silking and tasseling, soft dough stage) and at maturity. The sampling size was 1 m row length per plot at all stages except at final harvesting. Sampling rows are second from border. Dry weight was determined after oven drying at 65°C for 48 hours. The crop was harvested at milky-doughy phenological stage by removing the cobs from the plants and fresh cob weight with husk and without husk and the green fodder were also recorded.

Agronomic efficiency (kg cob yield/kg N applied) (AE<sub>N</sub>) of added fertilizer N was calculated as:

$$AE_N = (Y_N - Y_{N_0}) / Q_N$$

where Y<sub>N</sub> is the yield from N-fertilized plot, Y<sub>N<sub>0</sub></sub> is the yield from no N-applied plot, Q<sub>N</sub> is the quantity of N fertilizers applied. Exponential regression equations were fitted between cob yield and the readings recorded with different gadgets at different growth stages.

## RESULTS AND DISCUSSION

### Crop growth

In general, LCC, SPAD and NDVI readings were increased during the early growth stage, irrespective of the levels of N application. Indigenous sources and applied basal N dose continued to supply N for chlorophyll synthesis and thus green colour intensity of the leaves increased during early phase of the crop growth even in the control plot. After grand growth stage (V10) of the crop, steep decline in the readings was observed in the control. Whereas, these readings in other treatments were slightly influenced till grand growth stage. Leaf-area index and light interception (PAR) was significantly influenced by decision-support tools-based nitrogen fertilizer application (Table 2). At 60 DAS, of PAR was higher in application of N fertilizer @ 150 kg/ha and LCC 5, SPAD 50 over rest of the treatments. Whereas lower N application has resulted

**Table 1.** Total quantity and time of nitrogen fertilizers application based on decision-support tools threshold during 2014 and 2015

Treatment	Fertilizers applied (kg/ha)	Time of application (Days after planting)
Blanket 150 kg N/ha in 2 splits	150	0, 30, 45
Blanket 150 kg N/ha in 3 splits	150	0, 30, 45, 60
LCC threshold 4	90	15, 30, 45
LCC threshold 5	120	15, 30, 45, 60
SPAD threshold 40	60	15, 30
SPAD threshold 50	90	15, 30, 45
NDVI threshold 0.6	60	15, 30
NDVI threshold 0.8	120	15, 30, 45, 60
Basal application of 50% recommended N and urea foliar spray @ 2% at 30, 45 and 60 DAS	75	0, 30, 45, 60
Control (without N application)	0	–

in lower LAI as well as light interception. Singh *et al.* (2016) also indicated growth attributes of maize was significantly influenced by N management using LCC<5 and <5.5 at silking stage.

#### Biomass production

Biomass production of sweet corn was significantly influenced by rate of N application based decision tools ( $r^2=0.798$ ) (Fig.1). It was also observed that strong relationship between LCC thresholds and total dry-matter production at different intervals ( $r^2 = 0.85$ ). It has significant impact on biomass production. Further, LAI also indicated that significant regression with total dry matter production ( $r^2 = 0.76$ ). Application of higher rate of N application at 150 kg/ha had resulted in higher total dry-matter production but it was comparable with N application at lower rate based on LCC-5 SPAD 50 and NDVI 0.8 values. Raja (2001), Kar *et al.* (2006) and Oktem (2008), also reported significant impact of nitrogenous fertilizers on biomass

production of sweet corn.

#### Yield components

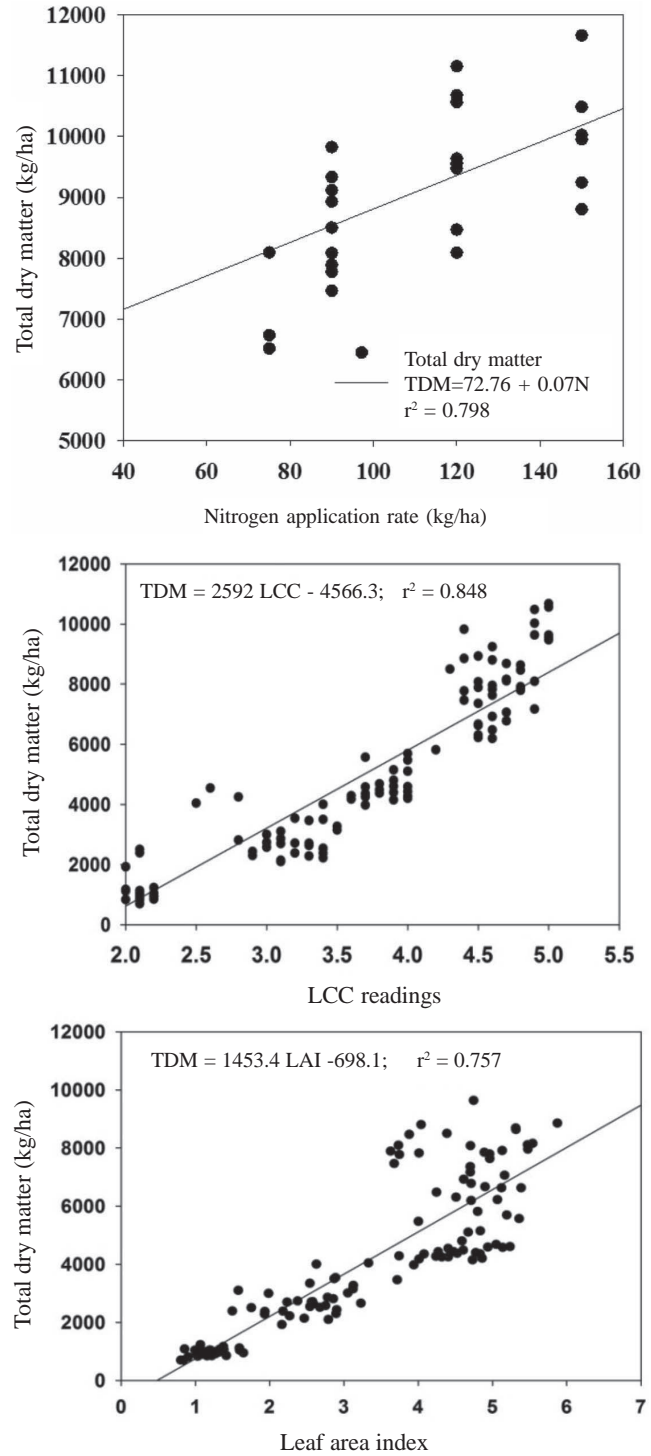
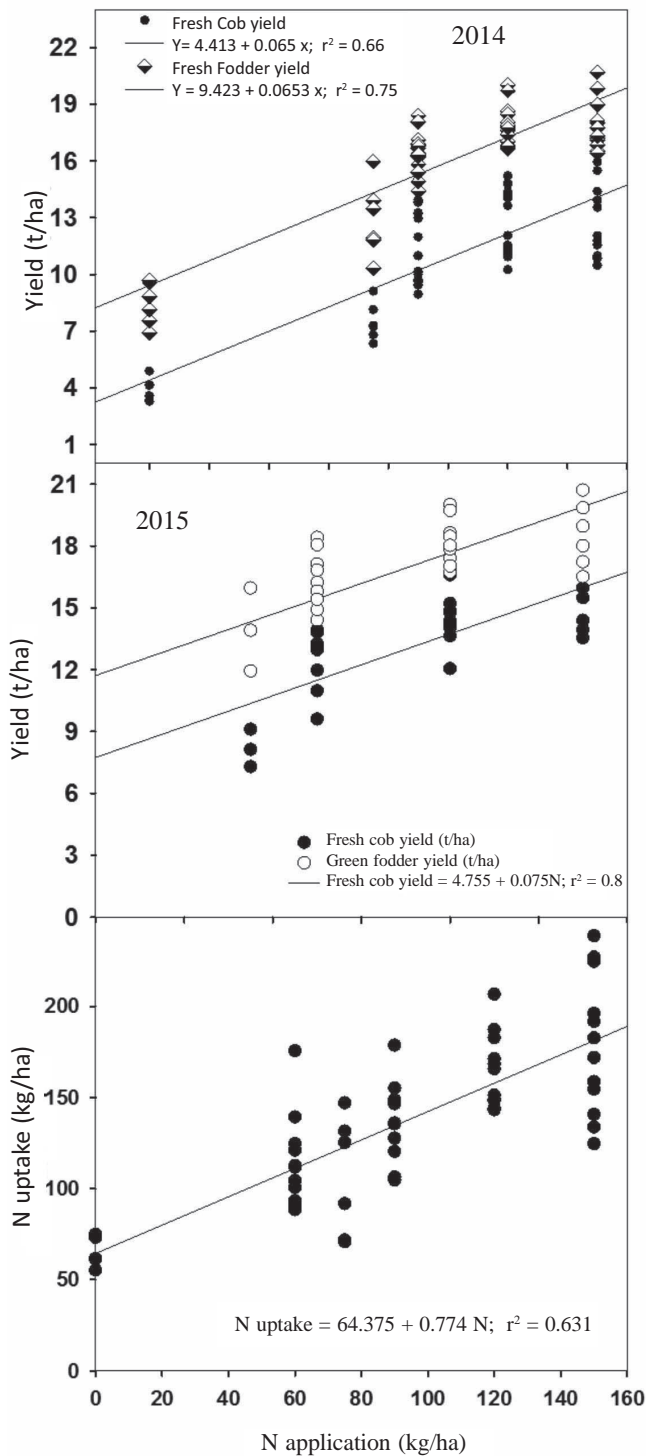
Application of N using different decision support tools resulted in significant differences with respect to fresh cob yield with and without husk (Table 2). The fresh cob yield with husk was higher with 150 kg/ha applied in 3 splits compared to all treatments followed by LCC 5, Green Seeker based NDVI 0.8 and 150 kg N/ha in 2 splits. Using LCC 5 as threshold led to the production of cob-yield equivalent to that produced with fixed-time application of 150 kg N/ha, but with the application of only 90 kg N/ha. These thresholds guided fertilizer N applications of 90 kg N/ha resulted in fresh cob yield comparable with fixed-time application of 150 kg N/ha. Comparable yield with 30 kg N/ha less fertilizer N was attributed to tailoring of the timings of fertilizer N applications. Blanket applications at fixed growth stages were not able to match fertilizer N supply with plant N demand and thus resulted in

**Table 2.** Yield and yield attributes of sweet corn under nitrogen recommendation techniques (pooled data of 2 years)

Treatment	Intercepted fraction of PAR at 60 DAS	No. of rows/cob	Grains/row	Fresh weight of cob (g)	Fresh cob yield with husk (t/ha)	Fresh cob yield without husk (t/ha)	Green fodder yield (t/ha)
<i>N application</i>							
150 kg N/ha in 2 splits	0.80	17.1	35.5	82.8	12.36	8.0	13.01
150 kg N/ha in 3 splits	0.84	12.3	25.7	94.8	13.72	9.3	14.79
LCC threshold 4	0.71	16.1	33.9	79.3	11.06	7.7	12.42
LCC threshold 5	0.83	17.4	37.2	81.3	13.23	8.1	14.40
SPAD threshold 40	0.75	14.8	30.4	78.1	9.92	7.6	12.62
SPAD threshold 50	0.8	15.8	31.8	89.5	11.47	8.5	13.02
NDVI threshold 0.6	0.79	14.8	28.9	61.7	10.09	5.8	12.28
NDVI threshold 0.8	0.78	17.4	37.4	81.5	13.02	7.5	13.98
50% N at basal and urea spray @ 2% at 30, 45 and 60 DAS	0.62	11.8	21.2	30.1	7.49	2.9	12.91
Control (without N application)	0.68	9.6	14.3	13.8	3.90	1.6	8.44
SEM±	0.04	0.77	1.91	4.90	0.32	0.50	0.49
CD (P=0.05)	0.11	2.3	5.7	14.6	0.94	1.5	1.45

yield comparable with need-based N-management strategy only if 30 kg or more fertilizer N was applied at fixed growth stages. Singh *et al.* (2010) also reported that, N can be efficiently manage by applying fertilizers based on LCC than blanket recommendation.

Strong relationship between fresh cob yield and N rate was observed as indicated by regression value  $r^2 = 0.66$  and  $0.80$  during 2014 and 2015 respectively (Fig.1). The magnitude of improvement in cob yield with the former treatment was 8 to 15% across different N recommenda-



**Fig. 1.** Linear relationship between variation in season above-ground biomass with LCC readings, leaf-area index (LAI), nitrogen application. Fresh cob yield, green fodder yield, N uptake of sweet corn relationship between nitrogen application rate throughout the growth stage and LCC, SPAD and LAI over 2 seasons

tion systems. Significant reduction in fresh cob yield of sweet corn was observed in treatment without receiving N. Among different N-recommendation techniques, LCC threshold 5 was out yielded LCC 4, SPAD 50 over SPAD 40 and Green Seeker NDVI 0.8 over NDVI 0.6. Further, foliar spray of 2% urea at 30, 45, 60 DAS resulted in lower cob yield of sweet corn. It might be due to foliar nutrition may not be sufficient to meet N requirement of sweet corn. Among the N levels, green fodder yield significantly higher with application of 150 kg N/ha in three splits. Further, sweet corn fresh fodder yield was also significantly influenced by N rate as indicated by  $r^2 = 0.75$  and  $0.80$  during 2014 and 2015 respectively (Fig. 1). Lower green fodder yield was recorded in without N application. Similar results on variation in biomass yield due to N application was also reported by Yao *et al.* (2014).

#### Quality of grain

Fresh cob quality parameters, viz. crude protein, oil and starch contents were higher with sufficient N application based on NDVI 0.8 and were at par with LCC 5, 150 kg N/ha either in 2 or 3 splits. Significantly lower crude protein, oil and starch contents were recorded in the control without N application. Since these quality parameters are directly N dependent, these parameters altered by variation in N supply. Among the decision tools there was no much deviation in quality of sweet corn grains. Oktem (2008) reported enhanced sugar and crude protein content in sweet corn with higher rate of N application, while current study also revealed higher values with lower N rates but supplied at critical time using DSS. Oketm *et al.* (2010) also reported that grain mineral content of sweet corn in-

creased with application of higher rate of N fertilizers.

#### Nutrient uptake and use efficiency

Uptake of nutrients is associated with the metabolic activities of plants, the concentration of the nutrients, dry-matter production and distribution. The higher N uptake was recorded with fixed time application of 150 kg N/ha either in 2 or 3 splits, whereas LCC threshold 5 and NDVI threshold 0.8-based N application recorded significantly higher N uptake over LCC 4, SPAD 40 and NDVI 0.6 at harvesting, as indicated by strong relationship ( $r^2=0.63$ ). Taufik *et al.* (2007) also reported significant improvement in nitrogen uptake in sweet corn through different fertilizer-recommendation techniques.

Irrespective of the decision tools, N application enhanced the agronomic efficiency of sweet corn. Higher agronomic efficiency of N (AEN) was recorded in SPAD 40, followed by NDVI at 0.6 and LCC thresholds also enhanced AEN as compared to application of 150 kg N/ha. It indicated that decision-support tools are effective in achieving higher AEN with fixed time of application. Balasubramanian *et al.* (2000) reported SPAD and LCC whereas Singh *et al.* (2011) found LCC threshold 5-based N application were effective in enhancing  $AE_N$  and  $PEP_N$  of maize.

The generally followed blanket recommendation of applying fixed N dose at fixed-time intervals was not adequate for obtaining high agronomic and recovery efficiency of fertilizer N in sweet corn. Thus, it can be concluded that matching fertilizer N supply with crop demand using LCC 5, SPAD 50 and Green Seeker guided NDVI 0.8 saved 20–40 % fertilizer N besides higher use and re-

**Table 3.** Quality of sweet corn grain, plant nitrogen concentration, nitrogen uptake and agronomic efficiency of N ( $AE_N$ ) under N application based on decision support tools (pooled data of 2 years)

Treatment	Crude protein (%)	Oil (%)	Starch (%)	Soil available N after crop harvesting (kg/ha)	Plant N (%)	Total N uptake (kg/ha)	$AE_N$ (kg fresh cob yield/kg N)
<i>N application</i>							
150 kg N/ha in 2 splits	8.65	7.5	70.9	202.5	2.4	167.4	55.2
150 kg N/ha in 3 splits	8.53	7.9	73.7	209.5	2.1	190.0	63.2
LCC threshold 4	8.18	7.6	70.6	191.7	1.6	137.8	88.1
LCC threshold 5	8.85	8.0	71.8	188.3	1.9	176.3	67.8
SPAD threshold 40	8.13	7.5	71.1	193.4	1.5	113.5	130.2
SPAD threshold 50	7.98	7.2	70.3	212.0	1.8	127.5	99.4
NDVI threshold 0.6	8.08	7.1	70.4	202.6	1.4	108.8	102.8
NDVI threshold 0.8	9.42	8.3	75.7	202.1	2.0	155.3	67.9
50% N at basal and urea spray @ 2% at 30, 45 and 60 DAS	7.22	6.7	69.4	206.9	1.8	106.4	40.0
Without N application	6.58	5.5	68.1	169.6	1.3	73.5	–
SEm±	0.31	0.23	2.22	–	0.09	6.94	4.51
CD (P=0.05)	0.92	0.7	6.6	–	0.28	20.6	13.4

covery efficiencies.

## REFERENCES

- Balasubramanian, V., Morales, A.C., Cruz, R.T., Thiyagarajan, T. M., Nagarajan, R., Babu, M., Abdulrachman, S. and Hai, L. H. 2000. Application of the chlorophyll meter (SPAD) technology for real-time N management in rice—A review. *IRRI Notes* **251**: 4–8.
- Blackmer, T.M. and Schepers, J.S. 1995. Use of a chlorophyll meter to monitor nitrogen status and schedule fertigation for corn. *Journal of Production Agriculture* **8**(1): 56–60.
- Kar, P.P., Barik, K.C., Mahapatra, P.K., Garmayak, L.M., Rath, B.S., Bastia, D.K. and Khanda, C.M. 2006. Effect of planting geometry and N on yield, economics and N uptake of sweet corn (*Zea mays*). *Indian Journal of Agronomy* **51**(1): 43–45.
- Ladha, J.K., Pathak, H., Krupnik, T.J., Six, J. and Kessel, C.V. 2005. Efficiency of fertilizer nitrogen in cereal production: retrospects and prospects. *Advances in Agronomy* **87**: 85–156.
- Moges, S.M., Raun, W.R., Girma, K., Freman, K.W., Zhang, H., Arnall, D.B., Tubana, B., Teal, R., Holtz, S.L., Walsh, O. and Chung, B. 2007. In-season estimation of grain sorghum yield potential using a hand-held optical sensor. *Archives of Agronomy and Soil Science* **53**: 617–628.
- Oktem, A. 2008. Effect of nitrogen on fresh ear yield and kernel protein content of sweet corn (*Zea mays* L. *saccharata*) under upper Mesopotamia region of Turkey. *Indian Journal of Agricultural Sciences* **78**(1): 50–52.
- Oktem, A., Oktem, A.G. and Emeklier, A.Y. 2010. Effect of nitrogen on yield and some quality parameters of sweet corn. *Communications in Soil Science and Plant Analysis* **41**(7): 832–847.
- Raja, V. 2001. Effect of N and plant population on yield and quality of super sweet corn (*Zea mays* L.). *Indian Journal of Agronomy* **46**(2): 246–249.
- Sahoo, S.C. and Mahapatra, P.K. 2007. Response of sweet corn (*Zea mays*) to plant population and fertility levels during *rabi* season. *Indian Journal of Agricultural Sciences* **77**(11): 779–781.
- Singh, V., Singh, B., Singh, Y., Thind, H.S. and Gupta, R.K. 2010. Need based nitrogen management using the chlorophyll meter and leaf colour chart in rice and wheat in South Asia: a review. *Nutrient Cycling in Agroecosystem* **88**: 361–380.
- Singh, V., Singh, Y., Singh, B., Thind, H.S., Kumar, A. and Monkia, V. 2011. Calibrating the leaf colour chart for need based fertilizer N management in different maize (*Zea mays*) genotypes. *Field Crops Research* **120**: 276–282.
- Singh, V., Bhatnagar A. and Singh A.P. 2016. Evaluation of leaf colour char for need based nitrogen management in maize (*Zea mays*) grown under irrigated condition in Mollisols. *Indian Journal of Agronomy* **61**(1): 47–52.
- Taufik, M., Yusuff, M., Osumanu, H.A., Asrina, W., Muhamad, N. and Majid, A. 2007. Effect of organic and inorganic fertilizers on nitrogen and potassium uptake and yield of sweet corn grown on an acid soil. *American Journal of Agriculture and Biology* **2**(2): 118–122.
- Teal, R.K., Tubana, B.S., Girma, K., Freeman, K.W., Arnall, D.B., Walsh, O. and Raun, W.R. 2006. In-season prediction of corn grain yield potential using normalized difference vegetation index. *Agronomy Journal* **98**: 1,488–1,494.
- Umesh, M.R., Shankar, M.A., Manjunatha, N. and Jagadeesha, N. 2014. Influence of nutrient supply levels on yield, nutrient uptake, grain quality and economics of corn (*Zea mays* L.) in *Alfisols* of Karnataka. *Indian Journal of Dryland Agriculture Research Development* **29**(1): 73–78.
- Yao, Y., Yuxin Miao, Qiang Cao, Hongye Wang, Martin L, Gnyp, Georg Bareth, Khosla, Rajiv, Wen Yang, Fengyan Liu and Cheng Liu. 2014. In-season estimation of rice nitrogen status with an active crop canopy sensor. *IEEE Journal* **7**(11): 4,403–4,413.