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Nano Urea Fertilization in Sweet Corn Using Leaf Colour Chart and Its Effect on Nitrogen Use Efficiency

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Broad based blanket recommendations of fertilizer nitrogen (N) in field may end up with lower N use efficiency because of large field-to field variability of soil N. At the identical time, crop should not suffer from the deficiency of N. Nitrogen fertilizer must be applied only when necessary and must be based on the crop's nitrogen status. So, keeping in view the significance of N on productivity, a field experiment was conducted during summer seasons of 2022 and 2023 on medium black calcareous

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soil at Junagadh (Gujarat) to study nano urea fertilization in sweet corn using leaf colour chart (LCC) and its effect on nitrogen use efficiency. Ten treatments comprising 40 kg N as basal (through DAP and urea) + 40 kg N through urea at 25-30 DAS (days after sowing) + 40 kg N through urea at 40-45 DAS (T_1), 40 kg N as basal + 40 kg N through urea at 25-30 DAS + two foliar spray of nano urea 0.4% (4 ml/l water) when LCC ≤ 4 (T_2), 40 kg N as basal + 30 kg N through urea at 25-30 DAS + three foliar spray of nano urea 0.4% when LCC ≤ 4 (T_3), 40 kg N as basal + 20 kg N through urea at 25-30 DAS + four foliar spray of nano urea 0.4% when LCC ≤ 4 (T_4), 40 kg N as basal + 20 kg N through urea at 25-30 DAS + three foliar spray of nano urea 0.4% when LCC ≤ 4 (T_5), 40 kg N as basal + 10 kg N through urea at 25-30 DAS + four foliar spray of nano urea 0.4% when LCC ≤ 4 (T_6), 40 kg N as basal + 10 kg N through urea at 25-30 DAS + three foliar spray of nano urea 0.4% when LCC ≤ 4 (T_7), 40 kg N as basal + four foliar spray of nano urea 0.4% when LCC ≤ 4 (T_8), 40 kg N as basal + three foliar spray of nano urea 0.4% when LCC ≤ 4 (T_9) and control (without N application) (T_{10}) in Randomized Block Design with three replications. Recommended dose of 60 kg P_2O_5 and 60 kg K_2O/ha were applied uniformly to all the plots as basal application. The experimental results revealed that 40 kg N as basal + 40 kg N through urea at 25-30 DAS + two foliar spray of nano urea 0.4% when LCC ≤ 4 recorded significantly the highest nitrogen, phosphorus and potassium uptake by cob and fodder and their total uptake by sweet corn, which remained at par with T_3 and T_1. Significantly maximum available nitrogen in soil after harvest of sweet corn was noted with T_1, which remained at par with T_2, T_3 and T_4. It can be concluded that nano urea fertilization in sweet corn using leaf colour chart ultimately resulted in improved nitrogen use efficiency, which also sustained the fertility of medium black calcareous soil.

Keywords: Leaf colour chart; nano urea; nitrogen use efficiency; nutrient content; uptake; sweet corn.

1. INTRODUCTION

“Sweet corn (*Zea mays* L. var. *Saccharata*) is a member of the *Poaceae* family. Sweet corn has worldwide importance due to its nutritional value and health benefits. It is not only used for food but its waste also has unique importance in industries and for animals. Sweet corn is gaining importance in the star hotels and urban areas for the preparation of special soups, sweets, jams, cream, pastes and other delicious eatables. Roasted green cobs of sweet corn provide starch, fat, protein, sugar, minerals and vitamin A (promoting better vision), B_3 (which supports metabolism, the nervous and digestive systems) and C in palatable and digestible form at relatively low cost” [1]. “The sweet corn's antioxidant activity is significantly increased when cooked, helping to battle cancer, heart disease and protect against cataracts. Sweet corn is perfect for those who want to maintain their youthful looks and remain young. It has a high content of antioxidants which prevent and slow down the aging process. At 86 calories per 100 g, sweet corn kernels are moderately high in calories in comparison to other vegetables” [2].

Nano urea (4.0% N w/v) because of its small size (20-50 nm) and higher use efficiency (> 80%), when sprayed on leaves of plant (2-4 ml/liter) at critical growth stages, it increases the instant availability of nutrients to the growing plant parts, increases chlorophyll formation, rate of photosynthesis, dry matter production and thus overall growth of the plants. Nano urea can easily penetrate the stomata and easily get entered through plasmodesmata and subsequently take part in the metabolism by binding itself with various carrier proteins. Unused nitrogen is retained in the plant vacuole and released slowly for appropriate plant growth and development [3].

“Real-time nitrogen management means synchronization between crop nitrogen demand and supply for improving nitrogen use efficiency and crop yield. Techniques used for real-time nitrogen management are leaf colour chart (LCC), chlorophyll meter/ SPAD meter (Soil Plant Analysis Development) and GreenSeeker” [4]. “The LCC consists of colour strips from yellowish green to dark green fabricated with veins matching that of crop leaves. In the LCC, the lightest and more yellowish hue is labeled-1, and the deepest, darkest green hue is labeled-6. The intensity of leaf colour shows the relationship between nitrogen and photosynthesis, making it an indicator of the amount of nitrogen present in the plant. Hence colour of crop leaves was measured to judge crop N status and its fertilization. LCC avoids excessive use of urea/other nitrogen fertilizers, improves NUE, improves soil fertility, increase crop health and productivity, reduces insect pest incidence which leads to less pesticide use, minimizes crop loss from lodging caused by excess N application, reduces greenhouse gas emissions, reduces the fertilizer related air and water pollution within and outside the farms and increases economic returns of farmers" [5].

"In the twenty-first century, the major challenge in modern agriculture is to increase nutrient use efficiency, with a particular effort on nitrogen in fields. Urea accounts for > 82% of the nitrogenous fertilizers applied to crops. The total urea consumption of India is 350 lakh MT. About 80 to 90 lakh MT of urea is imported" [6]. "Broad based blanket recommendations of fertilizer N in the field may end up with lower nutrient use efficiency because of large field-to field variability of soil N. Corn being an exhaustive crop, it requires a higher fertilizer dose. Insufficient nutrient availability to plants results in low yields and significantly reduced profits compared to a properly fertilized crop. The main reason for low N use efficiency is an inefficient splitting of nitrogen doses coupled with nitrogen applications more than crop requirements. It has been reported that application of fertilizer N in amounts more than that required to produce economic yields will lead to high N losses and low N use efficiency" [7]. Although LCC holds a major significance in nitrogen management in crop fields, it has not been popularized yet in India. The nitrogenous fertilizer recommendation must be according to crop demand. Therefore, physical examination of leaf colour intensity against standard LCC provides the plant nitrogen requirement in actual time and helps to manage the scheduling of N top dressing in crop. Taking note of the points highlighted above and considering the present scenario of farming, foliar application of nano urea using a leaf colour chart was aimed at improving nitrogen use efficiency in sweet corn.

2. MATERIALS AND METHODS

The study was conducted during the summer seasons of two consecutive years 2022 and 2023 at the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat). The soil of the experimental plot was clayey in texture and slightly alkaline in reaction with pH 8.34 and 7.97 and, EC 0.54 and 0.50 dS/m during 2022 and 2023, respectively. The soil was medium in available nitrogen (255.00 kg/ha and 250.50 kg/ha), available phosphorus (29.17 kg/ha and 31.00 kg/ha), available potassium (265.10 kg/ha and 272.70 kg/ha), available sulphur (17.00 and 16.50 mg/kg), available iron (5.90 and 5.17 mg/kg), available zinc (0.72 and 0.78 mg/kg), available manganese (9.20 and 10.00 mg/kg) and available copper (0.25 and 0.24 mg/kg) in summer 2022 and 2023, respectively.

The experiment was laid out in Randomized Block Design with ten treatments, which were replicated thrice with gross plot size of 5.0 m × 3.6 m and net plot size of 4.0 m × 2.4 m. The treatments comprised 40 kg N as basal + 40 kg N through urea at 25-30 DAS + 40 kg N through urea at 40-45 DAS (T_1), 40 kg N as basal + 40 kg N through urea at 25-30 DAS + two foliar spray of nano urea 0.4% when LCC ≤ 4 (T_2), 40 kg N as basal + 30 kg N through urea at 25-30 DAS + three foliar spray of nano urea 0.4% when LCC ≤ 4 (T_3), 40 kg N as basal + 20 kg N through urea at 25-30 DAS + four foliar spray of nano urea 0.4% when LCC ≤ 4 (T_4), 40 kg N as basal + 20 kg N through urea at 25-30 DAS + three foliar spray of nano urea 0.4% when LCC ≤ 4 (T_5), 40 kg N as basal + 10 kg N through urea at 25-30 DAS + four foliar spray of nano urea 0.4% when LCC ≤ 4 (T_6), 40 kg N as basal + 10 kg N through urea at 25-30 DAS + three foliar spray of nano urea 0.4% when LCC ≤ 4 (T_7), 40 kg N as basal + four foliar spray of nano urea 0.4% when LCC ≤ 4 (T_8), 40 kg N as basal + three foliar spray of nano urea 0.4% when LCC ≤ 4 (T_9) and control (without N application) (T_{10}). The seeds of sweet corn hybrid 'Sugar-75' were sown at the rate of 15 kg/ha at 60 cm × 20 cm spacing and raised with a standard package of practices. Nutrient application was done as per the treatment. 40 kg nitrogen was applied through DAP and urea as basal to all the plots except control. Recommended dose of 60 kg P_2O_5 and 60 kg K_2O/ha were applied uniformly to all the plots as basal application. IFFCO nano urea containing 4.0% total nitrogen (w/v) was used in this experiment. Foliar spray of nano urea 0.4% (4 ml/l water) was carried out with a knapsack sprayer using a flat fan nozzle with 500 liters of water per hectare for uniform spraying on the foliage during morning or evening hours avoiding dew.

The six panel Leaf Colour Chart (LCC) was used in the present experiment, which was developed for maize by scientists of Punjab Agricultural University (PAU). The methodology used for taking LCC readings is as under:

1. Starting from 21 DAS, LCC readings were taken from randomly selected 5 plants in each plot.

2. "Observations were taken from the third fully expanded and healthy leaf starting at the top of the sweet corn plant by matching the colour shade of LCC and average score of the 5 plants was worked out. The third fully expanded leaf from the head of maize was chosen for leaf colour measurement since this leaf is closely associated with the nitrogen status of sweet corn plant" [8]. At the time of tasselling stage, the ear leaf was used as an index leaf for measurement [9].
3. Readings were recorded by placing the middle part of the leaf on top of the LCC's colour strips for comparison.
4. Leaf was not detached.
5. Readings were taken at the same time of the day (8:00-10:00 AM).
6. The LCC was not exposed to direct sunlight during readings.
7. The same person has taken the first up to the last LCC reading.
8. If average reading below the critical LCC value, nano urea was sprayed as per treatment.
9. LCC readings were repeated after 7 days and the same 5 plants were observed up to the tasseling stage.

Plant samples collected at harvest from each net plot were sun dried for 24-48 hours in the field and then oven dried at 60-65 °C for 48 hours to a constant weight. The dried grain and fodder were finely ground in a 'Willey Mill' to obtain fine powder. These samples were subjected to chemical analysis for determination of nitrogen, phosphorus and potassium concentration by standard methods. Nitrogen (N) content in cob and fodder were determined on per cent dry weight basis as per method of Modified Kjeldahl's described by AOAC [10]. Phosphorus (P) content in cob and fodder was determined by Vanado-molybdo phosphoric yellow colour method using spectrophotometer at 470 nm as suggested by Jackson [11] and was expressed as percentage of phosphorus. Potassium (K) was extracted by neutral normal ammonium acetate (1:40) and then determined by the Flame photometer method [11]. Mean of dry matter yield of cob and fodder were used in computation of nutrient uptake.

Overall N use efficiency is also expressed as nitrogen partial factor productivity which indicates cob yield of sweet corn produced per unit of N supply. Nitrogen apparent recovery fraction denotes an increase in total N shoot uptake by sweet corn per unit of fertilizer N applied. Nitrogen agronomic efficiency indicates the increase in cob yield of sweet corn per unit of fertilizer N applied. The nitrogen use efficiency (NUE) indices *viz.,* nitrogen partial factor productivity, apparent recovery fraction and agronomic efficiency were calculated by using following formulas [12]:

$$\text{N partial factor productivity} \left(\frac{\text{kg}}{\text{kg}}\right) = \frac{\text{Cob yield (kg/ha)}}{\text{Quantity of N applied (kg/ha)}}$$

$$\text{N apparent recovery fraction (\%)} = \frac{\text{Total N uptake in treated plot (kg/ha)} - \text{Total N uptake in control plot (kg/ha)}}{\text{Quantity of N applied (kg/ha)}} \times 100$$

$$\text{N agronomic efficiency} \left(\frac{\text{kg}}{\text{kg}}\right) = \frac{\text{Cob yield in treated plot (kg/ha)} - \text{Cob yield in control plot (kg/ha)}}{\text{Quantity of N applied (kg/ha)}}$$

Representative soil samples were collected at the depth of 0-30 cm from each plot after harvest of crop and dried in shed. After drying, the samples were grinded in wooden mortar and pestle and sieved through 0.5 to 2.0 mm sieve according to the requirement of analysis. Soil available nitrogen was estimated by alkaline $KMnO_4$ method [13]. Soil available phosphorus was determined by Olsen's method [14]. Soil available potassium was determined by flame photometric method [11]. Soil organic carbon content was analyzed by chromic acid oxidation method [15].

3. RESULTS AND DISCUSSION

3.1 Effect on Nutrient Content of Sweet Corn

The pooled data of 2022 and 2023 furnished in Table 1 indicated that significantly the highest leaf N content at threshold value of LCC (2.237%) was observed with 40 kg N as basal + 40 kg N through urea at 25-30 DAS + 40 kg N through urea at 40-45 DAS (T_1), and it remained at par with T_2, T_3, T_4 and T_5. The application of 40 kg N as basal + 40 kg N through urea at 25-30 DAS + 40 kg N through urea at 40-45 DAS (T_1) recorded significantly maximum nitrogen content in cob (1.721%) and fodder (0.755%), which remained statistically similar with T_2, T_3 and T_4.

"The increased N content in cob and fodder of sweet corn might be due to better utilization of N from soil with well-developed root system owing to steady N supply throughout the crop growth stages, which might have resulted in adequate availability of N causing higher N content in plant at all the stages of crop growth. Improved N content in plant were due the combined application of nano urea and conventional fertilizers in above mentioned treatments, which improved the supply and uptake of N throughout the cropping period. It might be because LCC based foliar application of nano urea increased leaf N and total chlorophyll content and leaf photosynthetic rate were closely related" [16]. Similar results were also obtained by Maurya et al. [17], Thakur et al. [18] and Kanavi et al. [19].

3.2 Effect on Nutrient Uptake by Sweet Corn

It was evident from the pooled data presented in Table 2 that application of 40 kg N as basal + 40 kg N through urea at 25-30 DAS + two foliar spray of nano urea 0.4% when LCC ≤ 4 (T_2) recorded significantly the highest nitrogen, phosphorus and potassium uptake by cob (113.32, 32.69 and 41.94 kg/ha), fodder (63.68, 18.33 and 93.30 kg/ha) and their total uptake (177.00, 51.02 and 135.24 kg/ha) by sweet corn, respectively, which remained at par with T_3 and T_1.

In the present study, higher nitrogen, phosphorus and potassium uptake by cob and fodder and their total uptake by sweet corn might be attributable to early and abundant nutrient availability as evidenced from improvement in the nutritional status of plants at various growth stages of crop, which created a superior nutritional environment for root zone growth and development. It could be due to better plant growth and yield in LCC based nano urea application with better synchronized N demand and supply resulted in better N uptake throughout the crop growth period. Reddy and Pattar [20] and Yogendrakumar et al. [21] also suggested that higher N uptake by crop could be achieved with smaller amounts of N provided, as it was top dressed at appropriate times as observed with leaf colour chart based N management. The results are in close accordance with the findings of Avinash et al. [22], Choudhary et al. [23] and Thite et al. [24]. Nitrogen also promoted absorption of other nutrients including potassium and phosphorus. Application of recommended dose of P_2O_5 and K_2O might have maintained optimum P and K supply and plant P and K concentration. Increased uptake of phosphorus by sweet corn might be due to an increase in the amount of urea applied to the soil as nitrogen, which when nitrified produces hydrogen ions in addition to nitrate ions. It resulted in better extraction by roots and translocation within the plant system. Application of nano urea increased the uptake of N due to more surface area and permeability of nano urea which in turn increased the absorption of K nutrients also. The results confirm the findings of Maurya et al. [17], Sahu et al. [25], Patel et al. [26] and Arunkumar et al. [27].

3.3 Effect on Nitrogen Use Efficiency of Sweet Corn

"The data given in Table 3 pointed out that maximum nitrogen partial factor productivity (113.76, 115.52 and 114.64 kg/kg during 2022, 2023 and mean value, consecutively) was recorded with 40 kg N as basal + four foliar spray of nano urea 0.4% when LCC ≤ 4 (T_8). It might be due to saving of fertilizer N. The decreased nitrogen partial factor productivity with increasing in dose of N applied could be attributed to relatively less improvement in crop yield in presence of higher nutrient supplementation beyond a certain level as generally observed in all nutrients (law of diminishing returns). The increased nitrogen partial factor productivity using leaf colour chart resulted from better synchronization of timing of fertilizer N applications and the crop's need for N fertilizer. These results are in corroboration with the findings of" Kenchaiah et al. [28], Singh et al. [29], Kumar et al. [30], Bhavana et al. [31] and Nayak et al. [32]. Due to the lower rate of N application and lower N uptake, the treatments with lower cob yield produced higher nitrogen partial factor productivity and the treatments with higher cob yield produced lower nitrogen partial factor productivity. These findings reinforce the general belief that due to the rapid losses of nitrogen under increased application of nitrogen reduced partial factor productivity. This pattern of observations has been shown in previous works done by Zhu et al. [33] and Kumar et al. [34].

Further scrutiny of data (Table 3) revealed that application of 40 kg N as basal + 20 kg N through urea at 25-30 DAS + four foliar spray of nano urea 0.4% when LCC ≤ 4 (T_4) resulted in higher nitrogen apparent recovery fraction (200.28, 207.28 and 203.78 %) and agronomic efficiency (62.38, 64.82 and 63.60 kg/kg) in 2022, 2023 and mean value basis, respectively. The higher yields and N uptake with lesser N application were the major reasons behind the higher values of nitrogen apparent recovery fraction and agronomic efficiency. Bhat et al. [35] also highlighted that LCC based nitrogen application improved agronomic efficiency and reduced the N losses considerably. These results are exactly what one would expect for the N management program with a better synchronization between demand and supply. Similar results have been found by Gautam et al. [36], Thakur et al. [18], Riar et al. [37] and Kumar et al. [38].

Higher nutrient use efficiency was recorded with foliar application of nano urea mainly due to the higher nutrient uptake which increased the yield per kg nutrient applied. The nanocarriers of nano urea transported the nutrients in the right place, right time and acted as the right source, which ultimately enhanced the nutrient use efficiency of sweet corn. The results of the present investigation strongly support the findings of Chinnappa et al. [39], Mirji et al. [40], Patel et al. [26] and Sannathimmappa et al. [41]. In case of 40 kg N as basal + 40 kg N through urea at 25-30 DAS + 40 kg N through urea at 40-45 DAS (T_1), lack of synchronization in crop nitrogen demand with nitrogen application might resulted in more soil-plant system losses, thereby resulted in minimum nitrogen partial factor productivity, apparent recovery fraction and agronomic efficiency during consecutive two years of experimentation and on mean data basis. These results corroborate with the findings of Bhatia et al. [42], Bhat et al. [35] and Gayathri et al. [43].

3.4 Effect on Post-harvest Nutrient Status of Soil

The pooled data of the years 2022 and 2023 given in Table 4 indicated that significantly higher available nitrogen in soil (224.65 kg/ha) after harvest of sweet corn was noted under the application of 40 kg N as basal + 40 kg N through urea at 25-30 DAS + 40 kg N through urea at 40-45 DAS (T_1), which remained at par with T_2, T_3 and T_4. Available nitrogen in soil after harvest was increased significantly with increasing nitrogen dose which might be due to sufficient availability of N through applied fertilizers. This could be due to the right time of split application of nitrogen that prevented nutrient loss by leaching or volatilization and made continuous availability to crop. The results are in conformity with the work of Umbarkar et al. [44], Patel et al. [45] and Gousia et al. [46]. Though P_2O_5 and K_2O were applied at the recommended dose in all the treatments, they could not significantly affect the available phosphorus, potassium and organic carbon content in soil after harvest of sweet corn. The marginal diminution in the available nitrogen, phosphorus and potassium as well as organic carbon content over the initial values might be due to the fibrous root system of sweet corn which might have led to the exhaustive nature of the crop. Further, lower organic carbon status of soil after harvest was due to low incorporation of crop residues as well as rapid rate of decomposition due to high temperature in summer season. Similar results have been reported by Barad et al. [47], Sarwar et al. [48], Rathore et al. [49] and Chinnappa et al. [39].

Table 1. Effect of different treatments on nutrient content of sweet corn (pooled data of two years)

Treatments	Leaf N content at threshold value of LCC (%)	Nitrogen content in cob (%)	Nitrogen content in fodder (%)	Phosphorus content in cob (%)	Phosphorus content in fodder (%)	Potassium content in cob (%)	Potassium content in fodder (%)
T_1	2.237	1.721	0.755	0.485	0.208	0.610	1.102
T_2	2.215	1.701	0.748	0.489	0.216	0.627	1.121
T_3	2.188	1.680	0.720	0.481	0.210	0.624	1.112
T_4	2.152	1.634	0.703	0.478	0.203	0.614	1.094
T_5	2.120	1.562	0.670	0.468	0.201	0.605	1.081
T_6	2.000	1.542	0.645	0.467	0.198	0.593	1.060
T_7	1.955	1.518	0.633	0.458	0.197	0.583	1.042
T_8	1.875	1.500	0.613	0.448	0.194	0.578	1.030
T_9	1.842	1.480	0.592	0.440	0.188	0.569	1.017
T_{10}	1.785	0.849	0.340	0.416	0.176	0.511	0.914
SEm ±	0.044	0.036	0.019	0.016	0.008	0.024	0.042
CD (P=0.05)	0.127	0.103	0.056	NS	NS	NS	NS
CV (%)	5.31	5.80	7.39	8.37	9.80	9.90	9.78

Table 2. Effect of different treatments on nutrient uptake by sweet corn (pooled data of two years)

Treatments	Nitrogen uptake by cob (kg/ha)	Nitrogen uptake by fodder (kg/ha)	Total uptake of nitrogen (kg/ha)	Phosphorus uptake by cob (kg/ha)	Phosphorus uptake by fodder (kg/ha)	Total uptake of phosphorus (kg/ha)	Potassium uptake by cob (kg/ha)	Potassium uptake by fodder (kg/ha)	Total uptake of potassium (kg/ha)
T_1	107.02	61.31	168.33	30.59	17.20	47.79	38.48	89.28	127.76
T_2	113.32	63.68	177.00	32.69	18.33	51.02	41.94	93.30	135.24
T_3	107.78	60.19	167.97	30.75	17.59	48.34	39.98	91.03	131.00
T_4	100.02	56.58	156.60	29.04	16.27	45.31	37.41	86.39	123.81
T_5	84.63	48.88	133.51	25.20	14.61	39.81	32.77	77.47	110.23
T_6	81.71	46.63	128.34	24.81	14.36	39.16	31.37	75.19	106.56
T_7	70.72	44.19	114.91	21.13	13.73	34.87	27.02	71.45	98.47
T_8	69.22	39.97	109.19	20.69	12.62	33.31	26.84	65.59	92.43
T_9	63.18	37.14	100.32	18.73	11.81	30.53	24.27	62.54	86.81
T_{10}	19.97	13.71	33.68	9.33	7.08	16.42	11.54	36.92	48.47
SEm ±	3.32	1.79	4.09	0.95	0.54	1.19	1.21	2.98	3.03
CD (P=0.05)	9.51	5.14	11.73	2.74	1.55	3.40	3.47	8.56	8.69
CV (%)	9.94	9.29	7.76	9.61	9.20	7.52	9.52	9.76	7.00

Table 3. Effect of different treatments on nitrogen use efficiency of sweet corn

Treatments	Nitrogen partial factor productivity (kg/kg)			Nitrogen apparent recovery fraction (%)			Nitrogen agronomic efficiency (kg/kg)		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1	51.97	52.20	52.09	111.03	113.38	112.20	32.94	33.62	33.28
T_2	82.74	84.11	83.43	176.20	181.38	178.79	54.25	56.29	55.27
T_3	91.52	91.17	91.35	189.48	192.88	191.18	59.01	59.41	59.21
T_4	100.24	101.80	101.02	200.28	207.28	203.78	62.38	64.82	63.60
T_5	89.08	90.09	89.59	161.91	169.51	165.71	51.17	53.06	52.12
T_6	104.17	106.46	105.31	183.31	192.91	188.11	58.79	62.13	60.46
T_7	91.88	93.01	92.44	159.30	164.05	161.68	46.43	48.61	47.52
T_8	113.76	115.52	114.64	181.09	193.45	187.27	57.13	60.20	58.66
T_9	105.58	106.57	106.08	161.18	170.02	165.60	48.84	51.14	49.99
T_{10}	-	-	-	-	-	-	-	-	-

Table 4. Effect of different treatments on post-harvest nutrient status of soil (pooled data of two years)

Treatments	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)	Organic carbon (%)
T_1	224.65	25.72	213.66	0.64
T_2	215.36	25.93	220.54	0.63
T_3	213.04	26.12	223.58	0.62
T_4	206.00	26.30	225.19	0.61
T_5	196.73	26.59	228.37	0.61
T_6	194.47	26.66	238.86	0.60
T_7	190.19	26.79	241.79	0.59
T_8	181.25	27.51	243.07	0.58
T_9	173.73	27.88	245.28	0.58
T_{10}	171.17	28.01	248.52	0.57
SEm ±	6.60	0.91	8.48	0.02
CD (P=0.05)	18.92	NS	NS	NS
CV (%)	8.22	8.32	8.92	7.33

4. CONCLUSION

The experimental results revealed that 40 kg N as basal + 40 kg N through urea at 25-30 DAS + two foliar spray of nano urea 0.4% when LCC ≤ 4 recorded significantly the highest nitrogen, phosphorus and potassium uptake by cob and fodder and their total uptake by sweet corn, which remained at par with 40 kg N as basal + 30 kg N through urea at 25-30 DAS + three foliar spray of nano urea 0.4% when LCC ≤ 4 and 40 kg N as basal + 40 kg N through urea at 25-30 DAS + 40 kg N through urea at 40-45 DAS. It can be concluded that nano urea fertilization in sweet corn using leaf colour chart ultimately resulted in improved nitrogen use efficiency, which also sustained the fertility of medium black calcareous soil.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gebhardt SD, Matthews RH. Nutritive value of foods. USDA Human Nutrition Information Service. Home and Garden Bulletin, 72. Washington, DC; 1981.
2. Swapna G, Jadesha G, Mahadevu P. Sweet corn - A future healthy human nutrition food. International Journal of

Current Microbiology and Applied Sciences. 2020;9(7):3859-3865.
3. Anonymous. Nano fertilisers; 2021. Accessed 17 October 2021. Available: https://www.iffco.in/en/nano-fertilisers.
4. Muchhadiya RM, Sakarvadia HL, Gohil BS, Kumawat PD. Precision agriculture in crop farming. In: Jangre A, Jolly GE, Hazarika A, Mangaraj A, Muchhadiya RM, editors. Agronomy compendium: Diverse perspectives on crop science Volume-2. Stella International Publication, Kurukshetra. 2024;156-198.
5. Anonymous. Different types of leaf colour charts (LCCs). Nitrogen parameters, Chennai; 2023. Accessed 15 August 2023. Available:https://www.nitrogenparameters.com/leaf-color-chart.html.
6. Anonymous. Fertiliser production, import & sales in India during FY' 2022-23 till March; 2024. Accessed 10 January 2024. Available: https://fertiliserindia.com/fertiliser-production-import-sales-in-india-during-fy-2022-23-till-march/.
7. Fageria NK, Baligar VC, Li YC. The role of nutrient efficient plants in improving crop yields in the twenty first century. Journal of Plant Nutrition. 2008;31:1121-1157.
8. Clements HF. Interaction of factors affecting yield. Annual Review of Plant Physiology. 1964;15:409-422.
9. Peterson TA, Blackmer TM, Francis DD, Schepers JS. Using a chlorophyll meter to improve N management. University of Nebraska-Lincoln Cooperative Extension. NebGuide. 1993;G93-1171-A.
10. AOAC (Association of Official Analytical Chemists). Official methods of analysis of the Association of Official Analytical Chemists. Washington, DC; 2006.
11. Jackson ML. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi; 1973;498.
12. Cassman KG, Peng S, Olk DC, Ladha JK, Reichardt W, Dobermann A, et al. Opportunities for increased nitrogen-use efficiency from improved resource management in irrigated rice systems. Field Crops Research. 1998;56(1):7-39.
13. Subbiah BV, Asija GC. A rapid procedure for the estimation of available nitrogen in soils. Current Science. 1956;25:259-260.
14. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular USDA. Washington, DC. 1954;939:19.
15. Walkley A, Black IA. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 1934;37:29-37.
16. Muchhadiya RM, Kumawat PD, Sakarvadia HL, Chovatia PK. Response of sweet corn to nano urea under precision nitrogen management. Journal of Scientific Research and Reports. 2024;30(8):950-963.
17. Maurya NK, Singh YK, Tiwari US, Rajiv, Kumar P, Patel V, et al. Effect of need based nitrogen management on yield and quality of *kharif* maize (*Zea mays* L.) under central plain zone of U.P. The Pharma Innovation Journal. 2022;11(3):2361-2365.
18. Thakur A, Chandrakar T, Tedia K, Thakur AK, Singh DP, Deo HR. Effect of nano-urea on nitrogen use efficiency and yield of rice under upland bunded conditions. The Pharma Innovation Journal. 2022;11(2): 2817-2819.
19. Kanavi GBJ, Sunil C, Salimath SB, Mallikarjuna HB, Kadam PV, Jeevan HR. Evaluation of the effect of foliar nano nitrogen and zinc on chlorophyll (SPAD) and qualitative traits of green chilli in comparison with urea and $ZnSO_4$. International Journal of Environment and Climate Change. 2023;13(9):2317-2322.
20. Reddy BGM, Pattar PS. Leaf colour chart-a simple and inexpensive tool for nitrogen management in transplanted rice (*Oryza sativa*). Indian Journal of Agricultural Sciences. 2006;76(5):289-92.
21. Yogendrakumar, Tiwari KN, Nayak RK, Rai A, Singh SP, Singh AN, et al. Nanofertilizers for increasing nutrient use efficiency, yield and economic returns in important winter season crops of Uttar Pradesh. Indian Journal of Fertilisers. 2020;16(8):772-786.
22. Avinash B, Banerjee M, Duvvada SK, Paul SK, Malik GC. Response of rice (*Oryza sativa* L.) varieties to nutrient management in *kharif* season under lateritic soil of West Bengal. Biological Forum-An International Journal. 2023;15(8):326-333.
23. Choudhary MS, Intodia SK, Kaushik MK, Saharan V, Singh DP, Lakhawat SS, et al. Effect of nano urea on growth indices and grain yield of wheat (*Triticum aestivum* L.) under Southern Rajasthan conditions. Biological Forum-An

International Journal. 2023;15(8a):326-331.
24. Thite SD, Bodake PS, Chavan VG, Meshram NA, Sawardekar SV, Mhatre PP, et al. Precision nitrogen management in rice through nano urea by calibrating the leaf colour chart (LCC) in Konkan Region. The Pharma Innovation Journal. 2023; 12(12):2762-2766.
25. Sahu TK, Kumar M, Kumar N, Chandrakar T, Singh DP. Effect of nano urea application on growth and productivity of rice (*Oryza sativa* L.) under midland situation of Bastar region. The Pharma Innovation Journal. 2022;11(6):185-187.
26. Patel J, Tedia K, Bala J, Srivastava LK, Mishra VN, Banwasi RK, et al. Significance of nano N fertilizer on uptake, efficiency and yield of rice crop. Biological Forum-An International Journal. 2023;15(5):912-916.
27. Arunkumar MR, Fathima PS, Yogananda SB, Shekara BG. Influence of foliar application of nano urea and urea on productivity and nutrient status of fodder maize during *kharif* season. Journal of Experimental Agriculture International. 2024;46(5):428-434.
28. Kenchaiah K, Veeranna HK, Devaraju KM. LCC and SPAD based N management under different methods of sowing in rice. In: Abstracts of the 3rd CREMNET Workshop cum meeting in direct seeding and seeders in rice, Mysore. 2000;9.
29. Singh V, Singh Y, Singh B, Thind HS, Kumar A, Vashistha M. Calibrating the leaf colour chart for need based fertilizer nitrogen management in different maize (*Zea mays* L.) genotypes. Field Crops Research. 2011;120:276-82.
30. Kumar PP, Abraham T, Pattanaik SSC, Kumar R, Kumar U, Kumar A. Effect of customised leaf colour chart (CLCC) based real time N management on agronomic attributes and protein content of rice (*Oryza sativa* L.). Oryza. 2018;5(1):165-173.
31. Bhavana P, Laxminarayana A, Latha M, Anjaiah T. Judicious nitrogen management using leaf colour chart for enhancing growth and yield of short duration transplanted rice (*Oryza sativa* L.). International Journal of Current Microbiology and Applied Science. 2020;9(6):2850-2856.
32. Nayak R, Satapathy M, Rath B, Nayak RK. Yield, nutrient uptake and nutrient use efficiency of *kharif* rice (*Oryza sativa* L.) as influenced by different site specific nitrogen management practices in rice-groundnut cropping system. The Pharma Innovation Journal. 2023;12(2):2699-2703.
33. Zhu S, Vivanco JM, Manter DK. Nitrogen fertilizer rate affects root exudation: The rhizosphere microbiome and nitrogen-use-efficiency of maize. Applied Soil Ecology. 2016;107:324-333.
34. Kumar D, Patel RA, Ramani VP, Rathod SV. Evaluating precision nitrogen management practices in terms of yield, nitrogen use efficiency and nitrogen loss reduction in maize crop under Indian conditions. International Journal of Plant Production. 2021;15:243-260.
35. Bhat TA, Kanth RH, Jan B, Nazir A, Ahanger SA, Mir MS, et al. Real-time nitrogen application of rice varieties based on leaf colour chart under system of rice intensification in temperate climate. Agronomy. 2022;12:1-15.
36. Gautam S, Tiwari U, Sapkota B, Sharma B, Parajuli S, Pandit NR, et al. Field evaluation of slow-release nitrogen fertilizers and real-time nitrogen management tools to improve grain yield and nitrogen use efficiency of spring maize in Nepal. Heliyon. 2022;8:e09566.
37. Riar AS, Singh B, Kaur P, Singh R. Precision nutrient management through LCC in *kharif* maize (*Zea mays* L.). Agricultural Science Digest; 2023. Available: https://doi.org/10.18805/ag.D-5666.
38. Kumar A, Manjaiah KM, Sharma VK, Chobhe KA, Suman A, Bhatia A, et al. Evaluation of urea loaded nanoclay biopolymer composites with Zn and P solubilizing microbes for nitrogen uptake and use efficiency in maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system. Indian Journal of Agricultural Sciences. 2024;94(3):308-312.
39. Chinnappa SA, Krishnamurthy D, Ajayakumar MY, Ramesha YM, Ravi S. Effect of nano fertilizers on growth, yield, nutrient uptake and soil microbiology of *kharif* sorghum. International Journal of Environment and Climate Change. 2023; 13(10):2339-2348.
40. Mirji AC, Seenappa C, Amrutha TG, Rehaman HM, Chalapathy VV, Shilpa HD. Influence of nano urea on growth, yield and nutrient use efficiency of pigeonpea (*Cajanus cajan* L.) of Karnataka, India.

Biological Forum-An International Journal. 2023;15(9):403-409.

41. Sannathimmappa HG, Patil M, Channagouda RF, Patil C. Effect of nano nitrogen and nano zinc nutrition on growth and yield of irrigated maize in Southern transition zone of Karnataka. The Pharma Innovation Journal. 2023;12(1):1706-1709.
42. Bhatia A, Pathak H, Jain N, Singh PK, Tomer R. Greenhouse gas mitigation in rice-wheat system with leaf color chart-based urea application. Environmental Monitoring and Assessment. 2012;184: 3095-3107.
43. Gayathri PA, Ghuge SB, Shinde SA, Mahesh S, Pawar AV. Study of nitrogen rates and nano urea effects on physiological parameters and yield of safflower (*Carthamus tinctorius* L.). International Journal of Environment and Climate Change. 2023;13(10):3974-3981.
44. Umbarkar SP, Wagh AP, Umbarkar PS, Mane NV, Deokar SP. Effect of different levels of nitrogen and potassium on soil and plant nutrient analysis of sweet corn. Journal of Pharmacognosy and Phytochemistry. 2020;9(6):1135-1137.
45. Patel UJ, Deshmukh SP, Desai NB, Surve V, Mori MB. Impact of soil and foliar nutrient management practices on soil fertility in sweet corn (*Zea mays* var. *saccharata*). The Pharma Innovation Journal. 2021;10(12):600-602.
46. Gousia SU, Ajayakumar MY, Krishnamurthy D, Shankar AK, Bhat SN. Effect of nano nitrogen on growth, yield and nutrient uptake of Bt cotton. International Journal of Environment and Climate Change. 2023;13(11):3705-3710.
47. Barad BB, Mathukia RK, Der HN, Bodar KH. Validation of LCC and SPAD meter for nitrogen management in wheat and their effect on yield, nutrients uptake and post-harvest soil fertility. International Journal of Chemical Studies. 2018;6(3): 1456-1459.
48. Sarwar I, Gedam VB, Gajbhiye PN, Bhosale AS, Deshmukh DP. Effect of nano nitrogen on productivity of sweet corn (*Zea mays Saccharata*) and soil fertility in sub-montane zone of Maharashtra, India. Biological Forum-An International Journal. 2021;13(3b):246-250.
49. Rathore R, Hasan A, David AA, Thomas T, Reddy IS. Effect of different levels of nano urea and conventional fertilizer on soil health of maize (*Zea mays* L.) var, P3544 in an Inceptisols of Prayagraj, (U.P.) India. The Pharma Innovation Journal. 2022; 11(8):560-563.

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