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GreenSeeker for Efficient Utilization of Nitrogen in Maize: A Review

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

The GreenSeeker has emerged as a diagnostic tool to estimate nitrogen status of actively growing crop canopy, which measures the fraction of emitted light received by the sensor. Nitrogen plays a vital role in deciding growth and yield of maize crop. For economic profitability and environmental safety, it is required to go for precise management of nitrogenous fertilizer in maize. Several authors have worked on the efficacy of GreenSeeker for real time nitrogen management in maize. An attempt has been made to compile various research findings relating to effect of use of GreenSeeker on yield attributes, yield and economics of maize. Significant increase in maize yield was recorded by many of the researchers through dynamic nitrogen management practices involving split application of nitrogenous fertilizer based on NDVI value of GreenSeeker. Use of GreenSeeker resulted in higher values of gross return, net return and benefit-cost ration due to less use of nitrogen and enhanced rate of absorption by the plant. Hence, use of GreenSeeker can be a preferred option to enhance nitrogen use efficiency and minimize negative impact of chemical nitrogen on soil and water.

Keywords: GreenSeeker; nitrogen management; maize; NDVI.

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1. INTRODUCTION

Maize (*Zea mays* L.) or corn been globally recognized as a crop with multiple uses. It has also several synonyms like zea, silk maize, makka, barajovar, etc. (Kumar & Jhariya, 2013). The term 'mays' is derived from the word *mahiz* and *Zea* is a latin word, which means grain like wheat (Shah et al., 2016; Gayathri, 2022). Maize was cultivated as a field crop nearly 9,000 years ago in Southern part of Mexico (Kennett et al., 2020) considered the third most important crop worldwide (Hammad et al., 2025). Being a C_4 crop, maize is an efficient user of nutrients as compared to most of the C_3 crops (Atumo & Ayalew, 2023; Wang, 2024; Schmidt et al., 2009).

Maize has a wide climatic adaptability and a crop with versatile uses. As a multipurpose crop, maize is mainly used for preparation of human food, animal feed, fodder and valuable raw materials for industry (Erenstein et al., 2022; Sahoo and Mohanty, 2020). The crop serves as a staple food to a large population in the world and a major constituent for preparation of animal feed, especially fed to livestock and poultry (Klopfensteina et al. 2013). Besides, it serves as a key ingredient in many food products like cornmeal, corn syrup and cooking oil. Maize is used for producing bio-fuel, biodegradable plastic and other products. Maize is a crop, which can be used for various purposes. At the global level, around 56% of dry grain is used as animal & poultry feed, 13% for food and rest for other purposes. The multiple use of maize can be attributed to various colours of its kernels like yellow, white & blue). Hence, it is treated as one of the most important crop across world to address food and nutritional security with a considerable contribution to agrarian economy.

There are various types of corn viz. dent or flint corn, popcorn, waxy corn, baby corn, sweet corn, quality protein maize, high amylase maize, high oil maize, etc. (Serna-Saldivar and Carrillo, 2019). The diversity in maize is attributed to the variations in hardness &colour of the endosperm, type of starch found in the grains, kernel type, etc. (García-Lara et al., 2019). Maize is cultivated in an area of 208.23 M ha across the globe with productivity of 5.96 t/ha and total production of 1241.56 M tonnes. In India, the crop is grown in an area of 10.74 M ha with production and productivity of 38.09 M tonnes and 3.54 t/ha, respectively (FAOStat, 2023). Maize, being a C4 plant has higher photosynthetic as well as water use efficiency as compared to other cereals like rice and wheat.

2. ROLE OF NITROGEN IN MAIZE

Apart from abiotic and biotic stresses, poor soil fertility along with low nutrient use efficiency often limits maize production and productivity in India (Yadav et al., 2016). Nitrogen is the most important and deciding nutrient in cereal based cropping systems under irrigated ecosystem. It is essential constituent of nucleic acid, protein, chlorophyll and regulates many of the plant physiological processes. Nitrogen plays an important role in plant metabolism and determines the ultimate crop production and is a major deciding factor influencing yield and growth traits of maize across the world (Kathuli et al., 2023; Priyan, 2021; Wu et al., 2024). It is a major constituent of amino acids, proteins, chlorophyll and hormones required for growth and development of maize plant (Fathi, 2022). Nitrogen is subjected to various transformations after application in the field. Under natural conditions, the nutrient is prone to various changes like mineralization, nitrification, denitrification, volatilization, leaching, fixation in the organic clay colloids, etc. (Mohanty et al., 2015; Kumar et al., 2022). Nitrous oxide emitted by poor nitrogen management has higher potential of global warming, which is 310 times more than that of carbon dioxide. Excessive application of nitrogen fertilizer resulted in loss of the nutrient through leaching, which is a threat for aquatic lives (Jat et al., 2014). Hence, application of nitrogenous fertilizer should be in accordance with real time crop requirement and plant nitrogen uptake pattern, which regulates the production system.

Maize is grown under diversified climatic conditions under various geographic situations. Hence, it becomes difficult to identify reasons limiting productivity of the crop more precisely. However, among several factors, proper management of plant nutrients crucial and a deciding factor for yield of maize (Jat et al., 2013). Among various nutrients, nitrogen is regarded as the crucial nutrient for proper growth and development of maize plant (Maitra et al., 2019). For economic profitability and environmental safety, it is required to go for precise nitrogen management in maize. Yield estimation is needed for identifying accurate nitrogen requirement, which reduces the environmental risks associated with fertilizer N use (Ali et al., 2018).

There is wide scope to enhance the productivity and profitability of maize through precise application of agri-inputs like water and nitrogen (Rekha et al., 2022). As maize can be cultivated under different agro-climatic conditions, efficient nitrogen management through precision agricultural practices is being adopted to enhance maize yield on sustainable basis. Variable rate management strategies can address exact nitrogen requirements in different patches of a farm, which ultimately enhances land profitability (Prakasha and Mudalagiriyappa, 2018). Besides, the crop nitrogen requirement in maize is strongly influenced by agro-ecological situations (Colaco and Bramley, 2018). Early detection of nitrogen requirement in corn before the tassel emergence can significantly impact the ability to address these deficiencies, ultimately affecting the yield (Varvel et al., 2007).

Recommendation of nitrogen fertilizer dose without yield prediction leads to either over or under use of fertilizer in the crop field (Yao et al., 2012). Excessive application of nitrogen in plants make those susceptible to lodging, infestation of insects & diseases and waning of yield (Sujatha et al., 2024). Nitrogen application is to be harmonized with real time crop demand to enhance nitrogen use efficiency by reducing the loss of the nutrient from soil & plant system (Thakur et al., 2015). Hence, it is required to assess availability of nitrogen in soil to adjudge the quantum of application. Soil testing, visual diagnosis and foliar analysis are some of the prevailing approaches to determine nitrogen status in soil and plants. These approaches require lot of time & expenditure and necessitate analysis through destructive methods and the results are not available immediately to go for fertilizer application. Therefore, it is necessary to synchronize fertilizer application with plant need on real time basis so that nitrogen use can be optimized resulting in minimum harm to the immediate environment. Prediction of nitrogen requirement early in the season will help to make more informed decisions about split application of the nutrient to achieve desired outcomes (Sharma et al., 2025).

Hence, there is strong need for utilizing various sensors to provide apposite recommendations of nitrogen application to obtain maximum nitrogen use efficiency (NUE). In this circumstance, sensors are becoming more customary to assess nitrogen requirement of maize (Prakasha and Mudalagiriyappa, 2018).

3. GREENSEEKER

Modern technologies like optical sensors are used to assess nitrogen level in plants, which help to decide time and quantity of fertilizer application to obtain optimum yield. The sensors include GreenSeeker, SPAD meters, Crop Circle, etc. These censors measure chlorophyll content in the leaf surface and canopy reflectance in different wavelengths like red and near-infrared, which can indicate nitrogen status of the plant. The canopy sensors are used to develop site specific nitrogen management strategies through a non-damaging method, which can diagnose the nitrogen status of the plant on real time basis (Lu et al., 2020; Cao et al., 2017). The nitrogen need of the crop is assessed by various sensors used in the crop field and helps in taking informed decision to apply nitrogen fertilizer judiciously. The sensors utilize own light source to assess the nitrogen status of the plant by correlating the reflectance from crop canopy with leaf chlorophyll (Yao et al., 2012).

The GreenSeeker as a diagnostic tool, estimates nitrogen status of actively growing crop canopy and helps to decide time and quantity of fertilizer nitrogen top dressings. This device measures the fraction of emitted light, which is reflected back to the sensor and provides output as normalized difference vegetation index (NDVI) (Karthik et al., 2022). Other researchers (Kitić et al., 2019, Ngoune and Mutengwa, 2020) have defined GreenSeeker as a cheap hand-held remote sensing tool to make in-season assessment of crop health. GreenSeeker uses active radiation from red (671 nm) and near-infrared (780 nm) wavelengths to obtain reflectance data independent of solar light (Sujatha et al., 2024). GreenSeeker also measures plant biomass and displays it as NDVI, which assists in deciding nitrogen application more accurately. This is very much helpful to achieve the expected yield as compared to traditional nitrogen management practices. It also reduces pollution and enhances nitrogen use efficiency (Singh, 2017). With increase in rate of photosynthesis, there is higher absorption of red light by plants, resulting in less reflection. An increase in NDVI value obtained by GreenSeeker implies higher rate of photosynthesis (Stewart and Rosser, 2006). Additional application of nitrogen can be synchronized with the real time needs of the crop (Karthik et al., 2022).

4. NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

Normalized Difference Vegetation Index (NDVI) is used to assess the status of nitrogen in crop plant by analyzing various data obtained from various satellites (Tremblay et al., 2009). This is a scanner dependant system used to calculate crop growth rate by assessing nitrogen status in maize plant (Rambo et al., 2010). NDVI is obtained by analyzing the reflectance of red and near-infrared light from a surface. Specifically, NDVI is calculated by subtracting the red band reflectance from the near-infrared band reflectance and then dividing that difference by the sum of two reflectance values. This ratio helps to determine the presence and health of vegetation, as healthy vegetation reflects more near-infrared light and absorbs more red light.

The NDVI formula utilizes the difference in reflectance to assess vegetation:

$$NDVI = (NIR - Red) / (NIR + Red)$$

Where:

NIR is the value of reflectance observed at near-infrared band.

Red is the value of reflectance in the red band (Upadhyay et al., 2025).

Usually, the NDVI values range from -1 to +1. Values close to -1 indicate surfaces like water or snow without any vegetation. The value of 0 indicates bare soil or rock. Whereas, values closer to +1 specify high density and healthy vegetation due to the higher reflection of near infrared light and absorption of red light by chlorophyll. Change in NDVI value over time indicates the changes in health, growth or density of vegetation.

The information on efficiency of photosynthesis and yield potential is obtained by using the values of NDVI (Thenkabail et al., 2000). The biomass production per day is estimated through measurement of NDVI using optical sensor (Ratanoo et al.,2018). The NDVI reading obtained from the field is converted to recommendation of nitrogen by utilizing GreenSeeker algorithm. However, a particular algorithm varies depending on the situations of the crop field (Stewart and Rosser, 2006). GreenSeeker based nitrogen management has several impacts on crop growth, yield parameters, yield and economics of maize cultivation. Those are enumerated in the subsequent pages.

5. PLANT HEIGHT

Plant height is a fundamental characteristic used to assess plant growth and development, influencing factors like light interception, biomass and yield. Plant height is the reflection of growth and it is positively correlated with overall productivity of the plant. Higher plant height results in increased dry matter production (Prakasha and Mudalagiriyappa, 2018). GreenSeeker based nitrogen management have reportedly recorded significantly higher plant height (Rekha et al., 2022). Higher plant height can be attained due to increased nutrient availability, which contributed towards larger leaf area and higher chlorophyll content. Sujatha et al. (2024) reported significantly higher plant height in maize with application of 35% N as basal + 35% at 25 DAS + GS based N application at teaseling stage. This was at par with split application of nitrogen as 30% basal + 30% at 25 DAS + GS based N application at teaseling stage. The increment in plant height was due to uniform supply of the nutrient nitrogen during various crop growth stages of maize crop to fulfill real time requirement. In this way, the applied nitrogen could be better assimilated by the crop and enhanced the cell division and cell elongation. Bhuiya et al. (2020) corroborated these findings.

The plant height was improved under precision nutrient management practices through nutrient recommendation by use of GreenSeeker in karif maize (Shyam et al., 2021). Application of 75 % nitrogen as basal and rest as guided by GreenSeeker could record highest plant height in maize at tasselling stage. It was closely followed by application of 50% nitrogen as basal and rest as guided by GreenSeeker. This was ultimately translated to maximum plant height at harvest (Kumar et al., 2022). Pooniya et al. (2015) reported that site specific nitrogen management (SSNM) had a significantly improved the plant height in maize. Application of nitrogen guided by NutrientExpert and GreenSeeker resulted in taller plants during tassel initiation and maturity stages (Hasanain et al., 2024).

6. LEAF AREA

Leaf area is a crucial measurement in plant growth due to its role in photosynthesis, light interception and water use efficiency. It's often used in conjunction with leaf area index (LAI), which represents the total leaf area per unit of ground area. Synchronized application of nitrogenous fertilizer matching to the crop requirement results in higher rate of chlorophyll production in plants. This in turn translates to higher specific leaf weight and higher solar radiation interception, which triggers formation of more number of leaves in maize (El-habbal et al., 2010). Prakasha and Mudalagiriyappa (2018) observed higher leaf area in maize with GreenSeeker based nitrogen management. This finding was corroborated by Rekha et al. (2022), who could record significantly higher leaf area in maize with GreenSeeker based nitrogen management at NDVI value of 0.8. Pooniyaet al. (2015a) and Singh et al. (2015) found that site specific nitrogen management through GreenSeeker could result in higher LAI in maize.

Kumar et al. (2022) recorded higher leaf area index (2.11) at knee high stage of maize with application of 75% N as basal and rest as per recommendation of GreenSeeker value, which was followed by application of 50% nitrogen as basal and remaining nitrogen as per GreenSeeker value (1.95). Whereas, the lowest leaf area index of 1.41 was recorded with application of nitrogen in three equal splits at basal, knee high and silking stages. This may be attributed to supply of appropriate quantity of nitrogen to the plant as per real time requirement, which translated in to effective absorption, translocation and assimilation.

Nutrient application guided by NutrientExpert® and GreenSeeker recorded the higher leaf area index in maize than soil test-based fertilizer application. The increments were about 14.30 & 14.11 per cent at the knee-high stage and 10.80 & 10.60 per cent at the silking stage in a two years field experiment at IARI, New Delhi in the Northwestern Indo-Gangetic Plains (IGPs) of India (Hasanain et al., 2024).

7. DRY MATTER PRODUCTION

Rate of dry matter accumulation decides the ultimate crop growth and productivity. Being a C4 plant, the maize crop has greater efficiency for partitioning and translocation of photosynthates to different vegetative and reproductive parts of the plant during various growth phases (Pooniya et al., 2015; and Parihar et al.,2017). Singh et al. (2017) opined that nutrient management as per value based recommendations of Nutrient Expert (NE) and GreenSeeker (GS) could register higher growth parameters in maize. It may be attributed to plant nutrient supply considering soil inherent nutrient supply capacity and crop requirement. This was corroborated by the findings of Hasanain et al. (2024) who recorded enhanced dry matter accumulation with nitrogen management using NE+GS as compared to soil test-based recommendation (STBR). The tune of enhancement in dry matter accumulation was 8.7 % and 8.62 % at knee high and 4.70 % and 4.73 % at silking stage during first and second year of study, respectively due to nutrient management through NE+GS over STBR. GreenSeeker guided nitrogen application at NDVI value of 0.8 could result higher dry matter production in maize (Jyothsna et al., 2024) in an experiment carried out at Rajendra Nagar in Hyderabad.

Shyam et al. (2021) observed that the dry matter accumulation in maize was improved under precision nutrient management practices by applying nitrogen as per recommendation by Nutrient Expert (NE) and GreenSeeker (GS). Maximum dry matter accumulation was recorded at harvesting stage by applying nitrogen with use of NE, which was 22.0 per cent higher over state recommendation. Higher dry matter accumulation was reported with Nutrient Expert assisted site-specific nutrient management (SSNM) based fertilizer dosage as compared to blanket fertilizer application in cereal based cropping systems (Pooniya et al.; 2015).

8. YIELD ATTRIBUTES

Adequate supply of plant nutrients due to additional application of fertilizer accelerate the plant growth rate, which enhances yield and yield attributing factors. Additional production of photosynthates due to timely supply of nutrients to the plant results in considerably higher values of yield attributing characters (Dash et al., 2025). Among nitrogen management practices, the GreenSeeker-based nitrogen application could result in higher growth parameters, which was statistically comparable to SPAD-based N management (Maheswari et al., 2025).

Sruthi et al. (2018) conducted a field experiment on GreenSeeker based nitrogen management in hybrid maize and observed that provision of 215 kg nitrogen per hectare in five splits as per NDVI values (starting from 25 DAS till 55 DAS) recorded superior yield attributes as compared to application of RDN @ 180 kg N/ha. The higher quantity of N applied in more number of splits could result in higher cob length (23.6 cm), weight of cob (228.3 g/cob), number of kernels per row (38.2), number of rows per cob (16.8) and number of grains per cob ranged (641) as compared to application of RDN. Higher values of yield parameters were obtained because of supply of required nitrogen to support crop growth resulting higher recovery of the nutrient (Raj et al., 2018).

Sujatha et al. (2024) observed higher values of yield attributes like cob size, kernel count and kernel weight with split application of nitrogen and greenSeeker based topdressing at tasselling stage. Accurate provision of nitrogen to crop based on real time need resulted higher rate of photosynthesis and yield parameters as recorded by Boregowda et al. (2019), Nagarjun &Yogananda (2017), Joshi et al. (2017), Anand et al. (2017) and Shyam et al. (2021).

9. YIELD

The yield of maize grain was significantly influenced by GS based nitrogen management practices. Sujatha et al. (2024) reported that application of 35% N as basal + 35% N at 25 DAS + GS based N application at tasselling stage recorded significantly higher grain yield (7.13 t/ha) and stover yield (8.85t/ha). It was at par with application of 30% N as basal + 30% at 25 DAS + GS based N application at tasselling stage (6.98 t/ha and 8.7 t/ha). The grain yield was 11.93 per cent higher as compared to RDF.

Significant increase in maize grain yield by dynamic nitrogen management practices involving split application of nitrogenous fertilizer @ 180 to 320 kg/ha in 3 to 5 splits as per NDVI value of GreenSeeker was observed by Sruthi et al. (2018). The grain yield varied from 2966 kg/ha in absolute control (no nitrogen fertilizer application) to 8076 kg/ha in GreenSeeker based treatment, which received 215 kg N/ha in 5 splits. This result was in conformity with Biradar et al. (2013), who opined that real time N management with application of required dose of N at proper time was advantageous to enhance yield and profit of maize-wheat cropping system. It is imperative that the GreenSeeker guided nitrogen application develops a better source-sink relationship as this synchronizes the N supply as per crop requirement (Butche et al.; 2011; Pooniya et al., 2015; Baral and Adhikari, 2015; Rekha et al., 2022; Shivashankar et al., 2023).

Kumar et al. (2022) opined that optimum nutrient availability throughout the crop growth cycle can translate into higher grain yield in maize. Sufficient N supply, especially during critical crop growth stages as guided by GS could result in higher maize grain yield. This finding was corroborated by Jain and Maliwal (2022) and Shekhawatet al. (2021). Rekha et al. (2022) also reported significantly higher kernel and stover yield of 10.46 and 14.47 t/ha, respectively through GreenSeeker based nitrogen management at NDVI value of 0.8 as compared to other treatments.

Prakasha and Mudalagiriyappa (2018) from an experiment conducted at Bengaluru recorded significantly higher maize grain and stover yield (10.76 and 13.48 t/ha) with GreenSeeker based nitrogen management. This was attributed to higher number of cobs (1.92), higher cob length and girth (20.75 cm and 6.97 cm), a greater number of rows/cob (17.04), number of kernel/row (40.50) and higher test weight (37.68g). Similar findings were also reported by Arunkumar et al. (2017) and Dapake et al. (2016). Application of plant nutrients as per site specific nutrient management (SSNM) increased yield of maize crop (Sreelatha et al., 2012; Biradar et al., 2013). Similarly other researchers such as Mohanty et al. (2015), Kaur et al. (2016) conducted research in rice, cotton, sweet corn & maize and inferred that nitrogen management practices based on GreenSeeker technology resulted in higher yield as compared with conventional method.

10. NITROGEN USE EFFICIENCY

Assessment of the status of nitrogen in maize and wheat and its precise management can be possible by utilizing the data obtained from GreenSeeker (Erdle et al., 2011). Application of fertilizer N following SPAD and NDVI based Single Image (SI) approach registered significantly higher nitrogen Recovery Efficiency (RE) over soil test-based fertilizer N recommendation. The RE value of 78.0 per cent was recorded with application of 30 kg N/ha as basal and top dressing of N at NDVI 0.90. This treatment also recorded a higher Agronomic Efficiency of 34.2 kg grain kg/ N.

Upadhyay et al. (2025) from a five-year long field experiment from Meerut, UP recorded increased agronomic efficiency when Nutrient Expert and GreenSeeker were used for management of nitrogen in the field. The higher N Recovery

Efficiency and Agronomic Efficiency implies that time of fertilizer N application guided by NDVI value results in better synchronization of N supply with that of with crop N utilization pattern. These results are in consonance with findings of Attia et al. (2015), who recorded higher nitrogen use efficiency using SPAD meter technology in maize. Kitchen et al. (2010) found higher nitrogen use efficiency using NDVI based N management in maize. It can be inferred that the real time demand driven fertilizer N management using SPAD meter and GreenSeeker NDVI leads to improved nitrogen use efficiency.

11. ECONOMICS

Economic benefit is the ultimate indicator for acceptance of any agricultural technology. Precision nutrient management options positively impact the net return (Shyam et al., 2021). The net return increases with enhancement of grain and stover yield (Shekhawat et al., 2021). Sujatha et al. (2024) recorded higher gross return (Rs.114.43 thousand/ha), net return (Rs. 66.16 thousand/ha) and B:C ratio (2.35) from maize crop with 35% N application as basal + 35% at 25 DAS along with GS based N application at tasseling stage. Comparable gross return (Rs.112.02 thousand/ha), net return (Rs.64.14 thousand/ha) and B:C (2.32) were recorded in the treatment receiving 30% N as basal + 30% N at 25 DAS + GS based N application at tasselling stage. In both these treatments, the economic parameters were higher that RDF (gross return of Rs.108.55 thousand/ha, net return of Rs.59.89 thousand/ha and B:C ratio of 2.20). They reported 7.1 to 10.5 % higher net return by adoption of GS guided N management over RDF in maize. The higher economic return is due to increase in yield as well as reduction in the quantity of N fertilizer use. The results agree with the findings of Joshi et al. (2018) and Swamy et al. (2016).

Hasanain et al. (2024) reported maximum gross returns ($1544.73/ha in 1st year and $1599.38/ha in 2ndyear) and net returns ($918.29/ha in 1st year and $977.31/ha in 2nd year) in maize with nitrogen application as guided by NE+GS in a two-year field experiment conducted during 2018 & 2019 at ICAR-IARI, New Delhi. It was noticeably higher as compared to soil test-based fertilizer (STB) use. The maximum B:C ratio (1.47 in 1st year and 1.57 in 2nd year) were also registered under the same treatment having significant hike over STB (1.15 and 1.22). Kumar et al. (2022) reported highest net return of Rs. 97927 /ha in maize with application of 75% N as basal and rest as guided by GS. It was followed by net return of Rs. 91616 /hawith application of 50% N as basal and rest as guided by GS. Prakasha and Mudalagiriyappa (2018) reported higher B:C ratio (3.60) in treatment receiving GreenSeeker based nitrogen management during maize cultivation. This was mainly due to lower nitrogen fertilizer use (Biradar et al., 2013).

12.CONCLUSION

Maize is a heavy feeder requiring nitrogen during all its growth phases starting from germination to grain filling. Real time nitrogen management based on crop requirement not only minimizes application of fertilizer, but also helps in protecting soil and water from nitrogen contamination. GreenSeeker, an optical sensor has been proved to be highly effective to predict in-season nitrogen requirement in various crops. It has been successfully used to enhance maize yield potential across the globe. This enables precise nitrogen use at different growth stages, aligning with crop requirements specific to field and weather conditions. But, GreenSeeker can be useful to decide recommendation for basal nitrogen application in the crops. It also helps to reduce greenhouse gas emissions. GreenSeeker based corrective nitrogen application at different growth stages holds promise in achieving higher productivity, profitability and nitrogen use efficiency in maize. In the context of emerging development of frontier technology, it is imperative to embed application of Artificial Intelligence and Machine Learning with GreenSeeker in order to optimize nitrogen use in a cost-effective manner.

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 this manuscript.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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