

Leveraging Smartphone-Based Tools for Nitrogen Management: Insights into Photosynthetic Rate, Radiation Use Efficiency, and Fractional Interception of PAR in Maize

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ABSTRACT

Nitrogen (N) use efficiency in crop production remains low, with substantial losses impacting both economics and the environment. This study validated the Pusa N Doctor app, an innovative tool utilizing a dark green color index (DGCI)-based algorithm, for precision N management in maize during *kharif* 2023. Field experiments assessed N rates (0, 50, and 75 kg/ha) combined with App-based or Green Seeker™ (GS™) split N applications. Results indicated that N₇₅ PK + App achieved the highest photosynthetic rate (32.99 μmol CO₂/m²/s) and fractionally intercepted photosynthetically active radiation (fPAR) at 60 and 90 DAS. However, N₅₀ PK + App exhibited superior radiation use efficiency (5.05 g/MJ) with reduced N input (121.9 kg/ha). These findings underscore the app's potential to optimize N use, reduce fertilizer dependency, and enhance eco-efficiency in maize production, aligning with the UN SDG 12 for sustainable agriculture.

Key words: Dark green colour index, Normalized Difference Vegetation Index, Photosynthetic rate, Precision nitrogen management, Radiation use efficiency

In crop production, nitrogen (N) use efficiency—a measure of how much applied N is utilized in the harvested yield, is generally low, with a substantial portion often lost to the environment. This inefficiency not only reduces the effectiveness of fertilizers but also leads to significant economic losses and environmental issues, such as nitrate contamination in groundwater (Temkin *et al.*, 2019). To combat these problems, there is a growing emphasis among policymakers and agricultural stakeholders on transitioning toward resource-efficient farming practices. Precision technologies aimed at improving nutrient use efficiency are emerging as critical tools for ensuring global food security (Upadhyay *et al.*, 2025). Technologies like Green Seeker™ (GS™), SPAD meters, and leaf color charts (LCCs) have been developed to enable real-time N monitoring in crops. Despite their potential, these tools face practical limitations—GS™ and SPAD meters are costly and require com-

plex calibration procedures (Zhang *et al.*, 2017), while LCCs rely on subjective visual interpretation, making them less accessible to many farmers in India (Tao *et al.*, 2020).

Advancements in smartphone technology, however, offer new opportunities for addressing these challenges. In this context, a N prescription algorithm based on the dark green colour index (DGCI) (Karcher and Richardson, 2003) of maize leaf images were developed. After three years of experimentation, this algorithm was integrated into an android application named “Pusa N Doctor.” The app is designed to deliver real-time N recommendations for maize, helping farmers to optimize fertilizer use efficiently and sustainably.

Further the developed Pusa N Doctor application was validated in *kharif* 2023 in field experiments conducted with ‘PJMh-1’ variety of maize in ICAR-Indian Agricultural Research Institute, New Delhi (28° 4′ N latitude, 77° 12′ E longitude, 228.6 m above sea level), characterized by a semi-arid, subtropical climate, with a sandy loam soil (Typic Haplustept), having a pH of 7.7, 0.49% organic carbon, 223 kg/ha N, 16.8 kg/ha P, and 242 kg/ha K. The experiment was conducted in a randomised complete block design (RCBD), having 6 treatments, replicated 4 times. The treatments consisted of N applications at rates of 0 (N₀PK), 50 (N₅₀PK), and 75 kg/ha (N₇₅PK), supplemented with 75 kg/ha each of PO and KO as basal. Further, Pusa

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N Doctor app was used to apply 41.9 kg/ha and 30 kg/ha of N at 35 and 45 days after sowing (DAS) in the N_{50} PK + App treatment, and 58.6 kg/ha and 41.2 kg/ha of N at the same intervals in the N_{75} PK + App treatment. Similarly, in treatments utilizing GSTM technology, the N_{50} PK + GSTM treatment received 39.4 kg/ha and 36.4 kg/ha of N, while the N_{75} PK + GSTM treatment received 35.6 kg/ha and 33.7 kg/ha at 35 and 45 DAS. A total of 150 kg N/ha was given in the recommended dose of fertilizer (RDF) treatment, evenly split between the basal application and additional doses at 30 and 50 DAS. The crop was sown on July 4, 2023, using a tractor-drawn opener at a spacing of 60 cm × 20 cm and a seed rate of 20 kg/ha, in a randomized complete block design (RCBD).

The results of the experiment revealed that the fractionally intercepted photosynthetically active radiation (fPAR) was significantly affected by the N management practices (Fig. 1). The maximum fPAR was recorded at 60 DAS in all the N fertilized plots. N_{75} PK + App had the highest

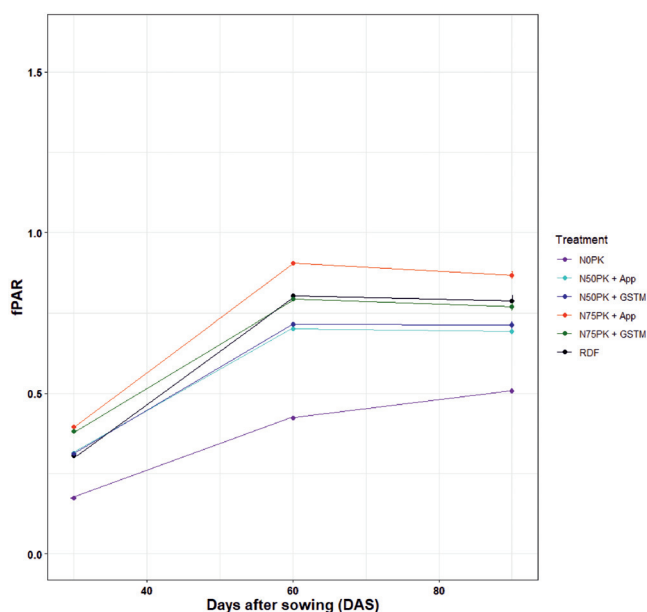


Fig. 1. Effect of nitrogen management practices on maize fractionally intercepted photosynthetically active radiation (fPAR).

fPAR at 30 (0.396), 60 (0.905) and 90 DAS (0.868). At 30 DAS, N_{75} PK + App was followed by N_{75} PK + GSTM (0.383), which were at par with each other as both of them received 75 kg/ha N as basal. The fPAR values progressively decreased in N_{50} PK + App (0.315), N_{50} PK + GSTM (0.312) and RDF (0.306), which were again comparable due to the same basal N dose of 50 kg/ha. At 60 DAS and 90 DAS, the fPAR values showed a similar trend, and was analogous to the cumulative N fertilizer application rate. N_{75} PK + App had significantly higher fPAR, compared to N_{75} PK + GSTM (0.793 at 60 DAS and 0.770 at 90 DAS) and RDF (0.804 at 60 DAS and 0.788 at 90 DAS), which were at par with other. Apart from the control plot the lowest fPAR was observed in N_{50} PK + App (0.702 at 60 DAS and 0.694 at 90 DAS) and N_{50} PK + GSTM (0.716 at 60 DAS and 0.713 at 90 DAS) which had no significant difference with each other. Higher N application have got a

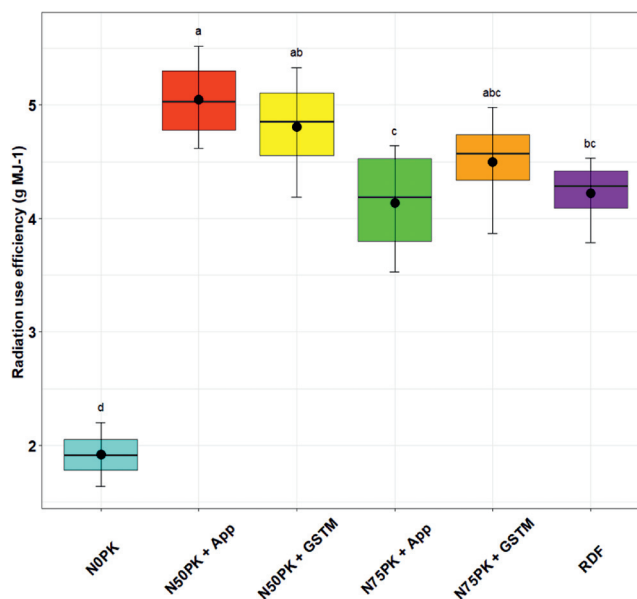


Fig. 2. Effect of nitrogen management practices on the radiation use efficiency (g/MJ) of maize. The different lowercase letters correspond to the treatments are significantly different at $p < 0.05$ according to LSD.

Table 1. Maize photosynthetic rate across the treatments at 30 DAS and 60 DAS

*Treatments	Maize photosynthetic rate ($\mu\text{mol CO}_2/\text{m}^2/\text{s}$)	
	30 DAS	60 DAS
N_0 PK	13.8 ^c	19.0 ^d
N_{50} PK + App	19.1 ^b	24.1 ^c
N_{50} PK + GS TM	19.6 ^b	25.7 ^c
N_{75} PK + App	22.4 ^a	32.9 ^a
N_{75} PK + GS TM	22.7 ^a	28.5 ^b
RDF	19.5 ^b	29.4 ^b

*For treatment details, please refer Table 2. Means followed by different lowercase letter within each column are significantly different ($p < 0.05$) according to LSD test.

positive impact on the leaf area index and leaf area increment of a crop, consequently enhancing the intercepted radiation (Patra *et al.*, 2023).

The photosynthetic rate in maize followed a trend similar to the fPAR (Table 1). The treatments applied with a higher basal N dose of 75 kg/ha had a higher photosynthetic rate (22.48 $\mu\text{mol CO}_2/\text{m}^2/\text{s}$ in N_{75} PK + App and 22.79 $\mu\text{mol CO}_2/\text{m}^2/\text{s}$ in N_{75} PK + GSTM) at 30 DAS. This was followed by the treatments applied with 50 kg/ha N as basal (i.e. N_{50} PK + App, N_{50} PK + GSTM and RDF). At 60 DAS, the photosynthetic rate was in accordance with the total fertilizer N amount applied in all the splits. N_{75} PK + App having the highest N dose of 174.9 kg/ha, had a significantly higher photosynthetic rate of 32.9 $\mu\text{mol CO}_2/\text{m}^2/\text{s}$, with a declining trend in RDF (29.4 $\mu\text{mol CO}_2/\text{m}^2/\text{s}$) and N_{75} PK + GSTM (28.59 $\mu\text{mol CO}_2/\text{m}^2/\text{s}$). Though, amongst the N fertilized plots the lowest photosynthetic rate was observed in N_{50} PK + App (24.1 $\mu\text{mol CO}_2/\text{m}^2/\text{s}$) it was at par with N_{50} PK + GSTM (25.7 $\mu\text{mol CO}_2/\text{m}^2/\text{s}$). N is a key component of chlorophyll, and being essential for the synthesis of enzymes like Rubisco, is crucial for the augmentation of leaf area, and thereby is highly correlated with rate of photosynthesis in plants (Sekhar *et al.*, 2021).

Radiation use efficiency was significantly higher in N_{50} PK + App (5.05 g/MJ) compared to N_{75} PK + App (4.13 g/MJ) and RDF (4.22 g/MJ), but was at par with N_{50} PK + GSTM (4.80 g/MJ) and N_{75} PK + GSTM (4.50 g/MJ). Radiation use efficiency which is usually calculated as a ratio of net biomass produced to the total intercepted photosynthetically active radiation (TIPAR), despite being a function of fertilizer N dose (Patra *et al.*, 2021), is higher in N_{50} PK + App treatment (which received 121.9 kg N/ha) compared to RDF and N_{75} PK + App treatments. This is mainly attributed to the at par biomass accumulation with a significantly lower TIPAR in N_{50} PK + App.

The results of this validation study thereby suggest that application of 50 kg N/ha as basal with two split doses of N as per Pusa N Doctor can lead to a significantly higher radiation use efficiency in maize, with a substantially lower dose of fertilizer N compared to RDF. Thereby, this Pusa N Doctor application holds a commendable future prospect in ensuring resource efficient agriculture, and will play a supplemental role in the accomplishment of the UN

SDG 12.

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