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Different Management of Nitrogen Application Affected Growth Characteristic of Maize (*Zea mays* L)

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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

A field study was conducted during *Kharif* 2019-20 at Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad, Telangana, India to evaluate different handheld decision support tools for precision nitrogen management in rainfed maize (*Zea*

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mays L.). The study utilized a randomized block design and was replicated three times. The eight treatments included applying nitrogen through the State-recommended dose of 200 kg ha-1 in three splits (RDN), using a leaf color chart (LCC) based on N at thresholds 3 and 4, using a soil plant analysis development (SPAD) chlorophyll meter based on N at thresholds 35 and 40, and using a Green Seeker based on N at NDVI 0.6 and 0.8 in comparison with RDN and absolute control. Based on Green Seeker NDVI at threshold 0.8, the results showed that applying nitrogen resulted in considerably greater yields for maize grain (8408 kg ha^{-1}), stover (9923 kg ha^{-1}), and harvest index (45.8%). with higher yield and growth parameter *viz.,* test weight (36.3 g), No. of grain rows row^{-1} (36.7), cob length (18.9 cm), plant height (223.7 cm), leaf area (6385.75 cm^2) and dry matter accumulation (18193 kg ha^{-1}) as compared to RDN. Similarly, Green Seeker based N at NDVI 0.8 also registered higher net returns (Rs. 118961 ha^{-1}) and B: C ratio (4.05).

Keywords: Grain yield; precision nitrogen management; maize; growth response; fertilizer use efficiency.

1. INTRODUCTION

"Maize (*Zea mays.* L) is one of the major cereal crops exhibiting wide adaptability to diverse agro-climatic conditions and stands first in production in the world. In India, it ranks third after rice and wheat". [1] Because of its greater production capacity and wider range of adaptation, maize is known as the "Queen of cereals". It needs an adequate supply of nutrients (N, P, and K). "Because maize is a labor-intensive crop and its hybrids respond well to fertilizer, a lot of nitrogenous fertilizer must be applied to the crop. More greenery and a quicker reaction to fertilizer application could be the outcome. When N application is not synchronized with crop demand, N losses from soil-plant system are large leading to low N fertilizer use efficiency. There is a need to synchronize the time of N fertilizer application and crop demand to optimize nutrient use efficiency and minimize environmental pollution. SPAD chlorophyll meter is faster than tissue testing for N and can help to assess when a plant needs more N" [2]. "Farmers generally use leaf colour as a visual and subjective indicator of the crop nitrogen status. Leaf colour chart (LCC) can be used as a complementary decision-making tool to determine the need for N requirement of crop. Under farm situations, LCC proved to be as good as the chlorophyll meter (SPAD) in terms of higher yield and improved nitrogen use efficiency" [3]. "It is an ideal tool to optimize N use, irrespective of the source of N applied [4,5]. Green Seeker is an improved tool based on optical sensors which emit brief bursts of red and infrared light, and then measures the amount of each type of light that is reflected from the plant, then the sensor continues to sample the scanned area as long as the trigger remains engaged and displays the measured value in terms of an NDVI reading" [6]. "The strength of detected light is a direct indicator of the health of crop and higher readings indicate better plant health" [7]. Hence, an experiment was conducted to find out the optimum threshold level of different handheld tools *viz*., LCC, SPAD and Green seeker for N application in rainfed maize.

2. MATERIALS AND METHODS

A field experiment was carried out at the main farm, Agricultural Research Station, Rajendranagar (17.19'N and 78.23'E) Hyderabad (India) during *Kharif* 2019-20 to know the performance of different decision support tools for effective nitrogen management in rainfed maize. With eight treatments and three replications of each treatment, the experiment was set up using a randomized complete block design (RBCD). The pH of the sandy loam soil at the experimental site was 7.46, and its electrical conductivity was 0.26 dS m^{-1}. The soil's organic carbon concentration is 0.45%, and its available nitrogen content was low (238.4 kg ha^{-1}) while its accessible potassium level was high (343.1 kg K_2O ha^{-1}). The hybrid maize cv. DHM-117 was used in the present study. The seeds were dibbled at 60 cm x 20 cm spacing. Applied in three splits, the treatments included the following: LCC-based nitrogen application at thresholds 3 and 4, SPAD-based nitrogen application at thresholds 35 and 40, Green Seeker-based nitrogen application at NDVI thresholds 0.6 and 0.8, and absolute control (no nitrogen). The state recommended dose of nitrogen (RDN) was 200 kg ha^{-1}. The pre-requisite quantity of fertilizer dose was applied as per-treatments. The recommended dose of 60 kg P_2O_5& 50 kg K_2O ha^{-1} in the form SSP and MOP and 35% RDN (except control) through urea were applied as the basal application for all the treatments. With the exception of control, the remaining treatments received the maximum dosage of nitrogen based on the crop's requirement as determined by the treatments (LCC, SPAD, and Green Seeker readings).

Two hand weedings were conducted at 25 and 45 days following sowing, after which Atrazine 50% WP @ 1.5 kg *a.i* ha^{-1} was sprayed to control weeds. Thirty days after sowing was when earthing up was done during the season. "The plant population was maintained in all the treatments by thinning out of excess seedlings at 12 DAS and leaving one seedling per spot. Healthy crop stand was ensured by adopting need-based crop protection and recommended packages of practices. Five plants were selected at random and tagged. These plants were used for recording growth parameters, yield attributes and yield". [1] The measurement of threshold readings through different tools was carried out as below:

Measurement of leaf colour chart: A leaf colour chart (LCC) developed by IRRI, Philippines and modified LCC developed by the Indian Institute of Rice Research (IIRR), Hyderabad (5 panel LCC) was used to measure the leaf colour intensity.

Measurement SPAD reading: The chlorophyll meter developed by the Soil Plant Analysis Development (SPAD) unit of Minolta Camera Company (SPAD 502) was used in this study as it instantly provides an estimate of leaf N status as chlorophyll content.

Measurement of Green seeker based NDVI reading: Green Seeker ™ handheld optical sensor unit Model 505 developed by U.S. Trimble Inc. was used to measure NDVI from the crop canopy.

Normalized Difference Vegetative Index (NDVI) measurements made by Green seeker were computed by the following equation:

NDVI = (NIR ref – RED ref)/ (NIR ref + RED ref)

where reflectance in the red and near-infrared regions is denoted by NIR ref or RED ref. A midseason estimate of the final grain output is made using the Normalized Difference Vegetative Index, which measures both the overall biomass and the greenness of the leaves.

Based on the cost of inputs, the economics was calculated and shown as Rs ha-1. The cost of cultivation was deducted from the gross returns for each treatment to determine net returns. The benefit-cost ratio (BCR) for each treatment was determined by multiplying the grain and stover yield by the prevailing market price, and gross returns were converted to rupees. Using a conventional technique, all the data were statistically evaluated [8].

3. RESULTS AND DISCUSSION

The amount of N applied for individual treatments and total quantity and the saving in N application is given in Table 1.

Significantly, higher grain yield (8408 kg ha^{-1}) was recorded with Green Seeker based NDVI at 0.8 (35 % RDN as basal and Green seeker based N at weekly intervals after 14 DAS)} which was on par with SPAD based N at threshold 40 (35 % RDN as basal and SPAD based N at weekly intervals after 14 DAS)} and Green Seeker based NDVI at 0.6 (35 % RDN as basal and Green seeker based N at weekly intervals after 14 DAS). The lowest grain yield (4343 kg ha^{-1}) was recorded in Control which was significantly inferior to all other treatments (Table 3). The yield of maize stover was significantly lower (6073 kg ha-1) when no nitrogen fertilizer was applied, and significantly greater (9923 kg ha-1) when nitrogen fertilizer was applied at the Green Seeker NDVI criterion of 0.8. (Table 3). Good nutrition or a balanced amount of nutrient treatment during the crop growth phases was clearly responsible for the greater grain and stover yield attained when N was regulated at Green Seeker NDVI threshold 0.8. Overall, it indicated that nitrogen application through NDVI value of green seeker 0.8 can be considered for achieving higher yield as they matched with crop N demand. These results are also in line with Kumar *et al*. [9] and Maiti and Das [10] who reported higher grain yield with LCC based nitrogen management. It is obvious that nitrogen as a major nutrient can influence leaf N and chlorophyll content and thus consequently SPAD and NDVI values, ultimately in the final yield [11] In present study higher harvest index (45.8 %) was registered with N application at Green Seeker NDVI threshold 0.8 as compared to other treatments (Table 3). Application of nitrogen in splits as per crop need at different crop growth intervals eventually led to better utilization of nitrogen for growth and development that might have resulted in a higher harvest index [12]. Similar results were reported by Shrabani *et al*. [13] in LCC based N management in rice.

Table 1. Application of nitrogen (kg ha-1) in accordance with LCC, SPAD, and green seeker readings

Treatments	Basal	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	49 DAS	56 DAS	No. of splits	Total N applied (kg ha^{-1})	Saving in N fertilizer over RDF
RDN (200 kg ha^{-1} in three equal splits	66.6	-	-	-	66.6	-	-	66.6	3	200	0
LCC based N application at threshold 3	70	-	-		32.5	-	-	32.5	3	135	65
LCC based N application at threshold 4	70			32.5		-	32.5	-	3	135	65
SPAD based N application at threshold 35	70	-	-	-	32.5			32.5	3	135	65
SPAD based N application at threshold 40	70	-	-	32.5	-	-	32.5	-	3	135	65
Green seeker based N application at NDVI value 0.6,	70	32.5	-	32.5	10	-	-	-	4	145	55
Green seeker based N application at NDVI value 0.8	70	32.5	-	32.5	10	10	10	-	6	165	35
Control (No nitrogen)	-	-	-	-	-	-	-	-	0	0	0

Table 2. Growth and yield components of maize as influenced by N management through different decision support tools

Treatments	Plant height at harvest (cm)	Leaf area (cm^2 $plant^{-1}$)	Dry matter accumulation (kg ha^{-1})	Cob length (cm)	No. of grains row^{-1}	100-seed weight (g)
RDN (200 kg ha^{-1} in three equal splits	216.4	4806.99	16326	17.8	34.0	34.1
LCC based N application at threshold 3	212.9	4542.83	15124	17.5	33.3	33.9
LCC based N application at threshold 4	217.6	4878.02	16244	17.9	34.6	34.2
SPAD based N application at threshold 35	213.4	4631.66	15476	17.6	34.2	34.0
SPAD based N application at threshold 40	222.4	6088.47	16880	18.8	35.8	36.1
Green seeker based N application at NDVI value 0.6,	219.4	5859.37	17136	18.6	35.6	35.9
Green seeker based N application at NDVI value 0.8	223.7	6385.75	18193	18.9	36.7	36.3
Control (no nitrogen)	176.5	3524.13	10303	11.8	22.7	23.7
SE(m) ±	1.6	392.53	497	0.30	0.64	0.70
CD (p=0.05)	4.8	1202.17	1523	0.9	2.0	2.1
CV (%)	5.6	13.3	5.5	3.0	3.4	3.6

Table 3. Grain yield, stover yield, harvest index and economics in hybrid maize as influenced by N management through decision support tools

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	BC ratio
RDN (200 kg ha^{-1} in three equal splits	7361	9015	44.9	39394	138493	96064	3.51
LCC based N application at threshold 3	7020	8761	44.4	38350	132313	93963	3.45
LCC based N application at threshold 4	7401	9069	44.9	38350	139326	100976	3.63
SPAD based N application at threshold 35	7051	8518	45.2	38350	132616	94266	3.46
SPAD based N application at threshold 40	7809	9386	45.4	38350	146825	108529	3.83
Green seeker based N application at NDVI value 0.6,	7783	9419	45.0	38483	146400	108212	3.80
Green seeker based N application at NDVI value 0.8	8408	9923	45.8	38942	157903	118961	4.05
Control (No nitrogen)	4343	6073	41.6	35319	82515	47196	2.33
SE(m) ±	1007	375	1.1	-	5798	5993	-
CD (p=0.05)	329	122	NS	-	17758	18353	-
CV (%)	8.1	6.4	4.2	-	7.6	11.1	-

Significantly higher cob length (18.9 cm), No. of grain per row (36.7) and hundred seed weight (36.3g) were recorded with N application at Green Seeker NDVI threshold 0.8 than the other treatments (Table 2). However, it was on par with N application at SPAD threshold 40 and Green Seeker NDVI threshold 0.6. These yield parameters were improved mainly due to increased growth performance represented by plant height, leaf area and dry matter accumulation. Similar results were reported by Premalatha [14] and Jayanthi et al. [15] Puneet [16] and Sruthi [17].

The increased yield under N application at Green Seeker NDVI threshold 0.8 resulted in an improvement of economic returns of maize production. In relation to the other treatments, N application at Green Seeker NDVI threshold 0.8 (Rs. 157903 ha^{-1} and Rs. 118961 ha^{-1}, respectively) registered the highest gross returns and net returns. This was followed by N application at SPAD threshold 40 and Green Seeker NDVI threshold 0.6 in relation to the suggested nitrogen dosage. Absolute control showed comparatively lower gross returns and net returns (Rs. 82515 ha-1 and Rs. 47196 ha-1, respectively) (Table 3). Higher grain and stover yields were the primary causes of these increased gross and net returns. n comparison to the other treatments, N application at Green Seeker NDVI threshold 0.8 resulted in a considerably higher benefit-cost ratio (4.05), which was statistically comparable to N application at SPAD threshold 40 (3.83) and N application at Green Seeker NDVI threshold 0.6 (3.80) (Table 3). Similar results were also reported by Maiti and Das [10] Ravi *et al*. [18] A higher economic return was realized in sweet corn by the use of green Seeker based NDVI value 0.8 as reported by Mallikarjuna Swamy *et al*. [5].

4. CONCLUSION

In present study, the treatment supplied with 70 kg N ha^{-1} as basal + remaining N (95 kg) as guided by Green Seeker at NDVI threshold 0.8 proved to be a superior treatment for the best management of N for rainfed maize in sandy loam soils over the recommended dose of nitrogen (RDN) 200 kg N ha^{-1} in terms of growth parameters, yield attributes and yield of medium duration hybrid maize with a saving of 35 kg of N.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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