Journal of Scientific Research and Reports

Volume 30, Issue 8, Page 305-312, 2024; Article no.JSRR.119857
ISSN: 2320-0227

Optimizing Input Management Practices for Sustainable Maize Production

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Authors' contributions

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

Article Information

DOI: https://doi.org/10.9734/jsrr/2024/v30i82252

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/119857

Original Research Article

Received: 16/05/2024
Accepted: 19/07/2024
Published: 27/07/2024

ABSTRACT

A field experiment was conducted to evaluate the effect of different input management practices on the growth, biomass production and yield of maize. The study was carried out during the rabi seasons of 2021-22 and 2022-23 at the Agricultural Research Farm, Bihar Agricultural University, Sabour, Bhagalpur. The experiment was laid out in a randomized block design with three

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Cite as: *Patel, Pritam Kumar, Suborna Roy Choudhury, Sanjeev Kumar Gupta, Anupam Das, Sushil Kumar Pathak, Devashish Kumar, and Chandan Kumar Panda. 2024. "Optimizing Input Management Practices for Sustainable Maize Production". Journal of Scientific Research and Reports 30 (8):305-12. https://doi.org/10.9734/jsrr/2024/v30i82252.*

replications. Seven nutrient management practices were tested in combination with pest management practices. The treatments included a 100% recommended dose of fertilizers (RDF) through inorganic sources, 50% RDF through inorganic and 50% through organic sources, SPAD-based nitrogen management, and the addition of insecticide application. The results showed that the treatment with SPAD-based nitrogen management and insecticide application (N6) resulted in the highest plant height (200.3 cm at 120 DAS), leaf area index (4.5 at 90 DAS), biomass production (19,156 kg ha-1 at harvest) and crop growth rate (24.2 g m-2 day-1 at 90-120 DAS). This treatment also recorded the maximum total biomass (19,538.33 kg ha-1), stover yield (7,103.33 kg ha-1), grain yield (9,896.67 kg ha-1), and harvest index (49.65%), which were significantly superior to the farmer's practice (N7). In conclusion, the nutrient management practice with SPAD-based nitrogen management and insecticide application can be an effective tool for maximizing the productivity of the maize crop.

Keywords: Growth parameters; Input management practices; maize; SPAD based N; yield.

1. INTRODUCTION

In India, maize is the third most important food crop after rice and wheat. According to the latest data of (DAC&FW, 2019-20), it is being cultivated on 1.748 m ha, i.e. 20-25 % area during rabi season. The current maize production is 9.34 MT, with an average productivity of 4.42 t ha^{-1}. Maize contributes nearly 9 % of the national food production. Nutritionally, it is rich in carbohydrates (70%), contains about 10% of protein and 4% of oil [1], and is thus considered to ensure food and nutritional security. Being an exhaustive crop, the nutrient requirement of maize cannot be supplied only through native nutrient reserves, and the additional nutrient requirements have to be met from organic and inorganic sources of nutrients. Maize requires more N and P than other essential elements for the development of all growth stages. Balanced application of plant nutrients through the integration of organic and inorganic fertilizers has been proven to enhance maize yield and soil fertility. Adoption of precision N management in maize crops increases the N use efficiency as well as reduces the N loss. Traditional farming following the blanket recommendation of fertilizer for maize crop can be replaced by the adoption of precision nutrient management, which saves the plant and soil health [2]. For many cropping systems in the tropics, application of N and P from organic and inorganic sources is essential to maximize and sustain high crop yield potential in continuous cultivation systems [3].

Focusing on income nutritional security, and sustainability, technologies like integrated input management have emerged as an option to grow a highly mining crop like maize. In comparison, the rice-maize system has proved to be a productive and profitable cropping system for eastern India and places where wheat productivity faces yield penalties due to delayed sowing after the late harvest of rice and terminal heat stress faced by wheat during its grain-filling period. Therefore, replacing the wheat crop with a more productive and remunerative maize crop can help in addressing the resource crush issues as well as the climate change and sustainability issues in a holistic manner. Efficient nutrient management is the key to increasing the productivity of maize; therefore, it requires the use of innovative and sustainable approaches. Precise information on the effect of different crop establishment methods, time of planting, and nutrient management strategies on the growth, productivity, and profitability of *rabi* maize is still lacking. Keeping in view the above consideration, present study has been formulated on the different input management practices on growth and yield attributes of maize crop.

2. MATERIALS AND METHODS

The field experiment was conducted during the winter (*rabi*) season of 2021-22 and 2022-23, at the research farm of Bihar Agricultural University, Sabour, Bhagalpur, Bihar to delineate sustainability in maize production system under varying source of organic and inorganic nutrients and their management along with seed treatment and insecticidal application. Source of input nutrient materials were supplied in the form of Urea (46% N), DAP (46% P_2O_5 and 18% N), and MOP (60% K_2O) and organic source of nitrogen given in the form of vermicompost. The experimental site is located in the Middle Gangetic plain locale of Agro-climatic Zone III (A) in Bihar (latitude-25°23'N, longitude- 87°07'E at an elevation of 37.19 meters above mean ocean level). The climatic condition of this place is tropical to subtropical and somewhat semi-arid in nature and is characterized by very dry summer, moderate rainfall and very cold winter. The soil was Gangetic alluvial type with sandy clay texture. Efficient nutrient management is the key to increasing the productivity of maize. Being a C4 plant, high yield potential hybrid maize is particularly responsive to nutrient treatment and requires more nutrients than the other traditional cereals. So, the adequate nutrient supply should be ensured from germination to the flowering stage of the plant. Nutrient deficiency occurred at any growth stages can severely affect the production level. Nutrient management practices have resulted in synergistic effects and improved synchronization of nutrient uptake and high yield, especially when the rates of chemical fertilizers used are relatively low. The target-enabled fertilizer management along with proper insecticidal application will aid in boosting the output and economic feasibility. Thus, the single experiment was established over two seasons. The seven nutrient management practices of maize crop viz N_1 (100% RDF (150:75:50 $N:P_2O_5:K_2O$ kg ha^{-1}) through inorganic fertilizer + Seed treatment with Bavistin @ 2.5 g/kg of seed), N_2 (50% RDN through inorganic fertilizer + 50% RDN through organic source + Seed treatment with Bavistin @ 2.5 g/kg of seed), N_3 (SPAD based N management + Seed treatment with Bavistin @ 2.5 g/kg of seed), N_4 (100% RDF through inorganic fertilizer + insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water), N_5 (50% RDN through inorganic fertilizer + 50% RDN through organic source + insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water), N_6 (SPAD based N management +insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water) and N_7 (Farmer's practice, 120:40:30 $N:P_2O_5:K_2O$ kg ha^{-1}) were applied in the present study. The field experiment was laid in a randomized block design (RBD) with three replications. The net plot size was 10m X 3.6 m. Maize (Variety P 1899) was sown in the month of November with a spacing of 60 cm x 20 cm. At the time of sowing as basal application of half dose of nitrogen and full dose of P_2O_5 and K_2O were applied. The remaining half doses of nitrogen were applied at two splits on 25 and 55 DAS respectively. In split nitrogen application, applying a portion at planting and the remainder at key growth stages of the plant (e.g., 50% at planting, 25% at knee-high, 25% at tasselling). In addition, the prescribed quantities of the organic manures viz., 50% RDN (75 kg of nitrogen) was supplemented with 2.5 t ha^{-1} of vermicompost (3.0: 1.0: 1.5 N: P_2O_5: K_2O kg ha^{-1}), applied as basal. Under the SPAD based treatments, nitrogen was top dressed in the form of urea at the rate of 20 kg ha^{-1}whenever the SPAD meter reading was below the critical threshold value 46.1 (average SPAD reading of 3 plants were taken). The threshold value was determined and validated from previously conducted experiment at same location. The SPAD measurement were taken from a chlorophyll meter (SPAD 502, Soil Plant Analysis Development) by inserting at mid-length of the third leaf from the top and closing the measuring head at every 25-30 days interval. The insecticide, chlorpyriphos 20 EC was sprayed at 5-10% infestation of fall armyworm and stem borer as per the state released recommendation dose. The five (05) irrigations were given at the critical growth stages of the crop (Seedling stage, knee-height stage, tasselling stage, silking stage, grain filling stage) and for weed control Atrazine 50% @1.0 kg ha^{-1} at 2 DAS followed by Tembotrion 34.5 EC @ 120 g a.i. ha^{-1} at 25 DAS were given as per the state released recommendation dose. Maize crop was harvested at its 80% physiological maturity. Observations were recorded at periodic intervals (30, 60, 90 DAS, 120 DAS and at harvest) on growth parameters viz. plant height, Leaf area index (LAI), biomass production and crop growth rate (CGR). The plant height was measured from the base of the stem (ground level) to the growing top most leaf of the randomly tagged pants. The total amount of above- ground biomass generation was estimated using the plants combined dry weights. For LAI measurement, the leaf blades were separated from the shoot and the total area was measured by the leaf area meter (LI-3000 Leaf Area Meter LI-COR Ltd. Nebraska, USA). Average leaf area per unit area was used for computation of LAI [4] which is the ratio between the area of the surface of green leaves and the ground area covered.

$$\text{Leaf area index (LAI)} = \text{Leaf Area } (cm^2)/\text{Ground area } (cm^2) \times 100$$

The CGR [5] was worked out with following formula:

$$\text{Crop growth Rate} = W_2\text{-}W_1 / t_2\text{-} t_1$$

Where, W_2 and W_1 are the final and initial dry weight of the crop at the time t_2 and t_1 respectively. The unit of CGR is g m^{-2} day^{-1}.

Total biomass production and yield parameters and yields were recorded at the time of harvest. The data obtained with respect to crop growth parameters and yields were subjected for statistical analysis of variance methods outlined by Cochran and Cox [6], Panse and Sukhatme [7]. The significance of treatment effects was computed with the help of 'F' (variance ratio) test and to judge the significance of differences between means of two treatments, critical differences (CD) was worked out. The mean values were grouped for comparisons and the least significant differences among them were calculated at $P < 0.05$ confidence level using ANOVA statistics as outlined by Gomez and Gomez [8]. The two (02) years pool data pertaining to growth attributes and yield of maize were presented in tables from 01 to 05.

3. RESULTS AND DISCUSSION

There was progressive increase in plant height (Table 1) with increase in age of crop up to 120 DAS and slowed down thereafter indicating that grand growth period lies between 60-120 DAS. The plant height increased significantly with increasing level of nutrient management practice except at 30 DAS. Fundamentally, nitrogen is an essential macronutrient for plant growth and development and it mostly involves in synthesis of nucleotides, protein, enzymes as well as chlorophyll level in the plants which accelerates the plant height [9]. Tallest plant produced (169.1 cm) with the treatment N_6 (SPAD based N management +insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water) which remained at par with the treatment N_4 (165.9 cm) received 100% RDF through inorganic source along with insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water). LAI (Table 2) was recorded maximum (2.1 and 3.5 at 60, 120 DAS respectively) with N_6 (SPAD based N management +insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water) which remained at par with treatment received N_1 (100% RDF (150:75:50 $N:P_2O_5:K_2O$ kg ha^{-1}) through inorganic fertilizer + Seed treatment with Bavistin @ 2.5 g/kg of seed), N_2 (50% RDN through inorganic fertilizer + 50% RDN through organic source + Seed treatment with Bavistin @ 2.5 g/kg of seed), N_3 (SPAD based N management + Seed treatment with Bavistin @ 2.5 g/kg of seed) and N_4 (100% RDF through inorganic fertilizer + insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water)at 60 and 120 DAS. Basically, SPAD based nutrient management can supply the nutrients as per the need of the plant that aids to create a favourable environment for the plant along with proper herbicidal and pesticidal application, promotes better growth by mining more nutrients and water from the deeper layer of the soil with its voluminous root mass [10]. A consistent increase in the biomass production (Table 3) occurred with the advancement of the crop growth stages and reached to maximum at time of maturity. It is evident from the data that biomass production increased significantly with the application of treatment N_6 (SPAD based N management +insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water) and that was significantly higher than the treatments (N_2, N_5 and N_7), although statistically at par with N_4 and N_3 at 60, 90 DAS. In the treatment N_6 nutrient was applied as per the need of the crop and reduce the chances of nitrogen losses through weeds, leaching, nitrification as well as denitrification, and volatilization, expressing higher growth attributing characters of the crop [11]. Likewise, crop growth rate (Table 4) was more pronounced when treatment N_6 (SPAD based N management +insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water) (9.83 g m^{-2} day^{-1}) was given. Crop growth rate were recorded maximum with N_6 (SPAD based N management +insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water) (24.2 g m^{-2} day^{-1} and 14.6 g m^{-2} day^{-1} at the growth period of 90-120 DAS and at 120 DAS- Harvest respectively) which remained at par to the treatment received N_1 , N_2, N_4 andN_5, but found significantly superior over inorganic source N_7(farmer's practice) (18.4 g m^{-2} day^{-1} and 9.7 g m^{-2} day^{-1} at the growth period of 90-120 DAS and at 120 DAS-Harvest respectively). By providing exact amount of nutrient at right time can attribute to better growth rate of the plant. Significantly highest stover yield recorded with N_6 (SPAD based N management +insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water) (7103.33 kgha^{-1}) but found significantly superior over N_7 (farmer's practice) (6766.67 kg ha^{-1}) and N_2(50% RDN through inorganic fertilizer + 50% RDN through organic source + Seed treatment with Bavistin @ 2.5 g/kg of seed) (6781.33 kg ha^{-1}) (Table 5). Similarly, grain yield enhanced significantly (9896.67 kg ha^{-1}) with the application of SPAD based N management +insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water (N_6) and the same trend was followed in stone yield also, where the maximum stone yield (2538.33 kg ha^{-1}) was recorded in N_6 but remained at par to N_4 (2486.00 kg ha^{-1}) and the minimum stone yield was recorded (1665.0 kg ha^{-1}) in N_7 (farmer's practice) (Table 5). This may be due to the fact that the good root biomass can generate greater xylem exudates and can transport those towards shoot at faster rates. These feature helps to enhance the chlorophyll level, enhance fluorescence and photosynthesis rates in the leaves, augment the yield level [12]. However, the harvest index of maize did not influence significantly with different nutrient management treatments [13,14].

Table 1. Effect of nutrient and pest management practices on plant height of maize

Treatment	Plant height (cm)				
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**At harvest**
N_1	24.5	100.0	162.5	195.5	194.3
N_2	23.1	97.3	159.2	193.4	190.6
N_3	24.8	100.9	163.4	197.5	196.8
N_4	25.0	102.6	165.9	198.8	198.0
N_5	23.5	98.1	162.1	194.1	192.6
N_6	25.3	104.3	169.1	200.3	198.9
N_7	22.4	96.0	155.0	192.2	190.2
SEm (±)	1.01	0.29	1.62	0.93	1.21
CD (P=0.05)	NS	0.89	4.83	2.87	3.72

Table 2. Effect of nutrient and pest management practices on LAI of maize

Treatment	Leaf area index (LAI)				
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**At harvest**
N_1	0.4	1.9	4.3	3.2	2.2
N_2	0.3	1.4	4.0	2.9	2.1
N_3	0.4	1.8	4.3	3.3	2.3
N_4	0.4	1.9	4.4	3.4	2.3
N_5	0.3	1.5	4.3	3.1	2.2
N_6	0.4	2.1	4.5	3.5	2.4
N_7	0.3	1.2	3.9	2.8	1.9
SEm (±)	0.02	0.10	0.30	0.23	0.29
CD (P=0.05)	NS	0.32	NS	0.68	NS

Table 3. Effect of nutrient and pest management practices on biomass production of maize

Treatment	Biomass (g m^{-2})				
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**At harvest**
N_1	37.35	268.22	700.85	1384.99	1802.02
N_2	36.35	232.94	667.16	1264.18	1531.95
N_3	37.78	287.78	736.29	1434.45	1823.32
N_4	38.76	327.45	755.08	1469.67	1859.99
N_5	36.92	249.28	687.76	1334.40	1665.73
N_6	38.93	333.89	771.88	1498.80	1915.60
N_7	36.05	222.50	636.95	1190.28	1482.54
SEm (±)	0.982	15.80	18.21	44.07	41.93
CD (P=0.05)	NS	48.68	54.83	135.80	129.18

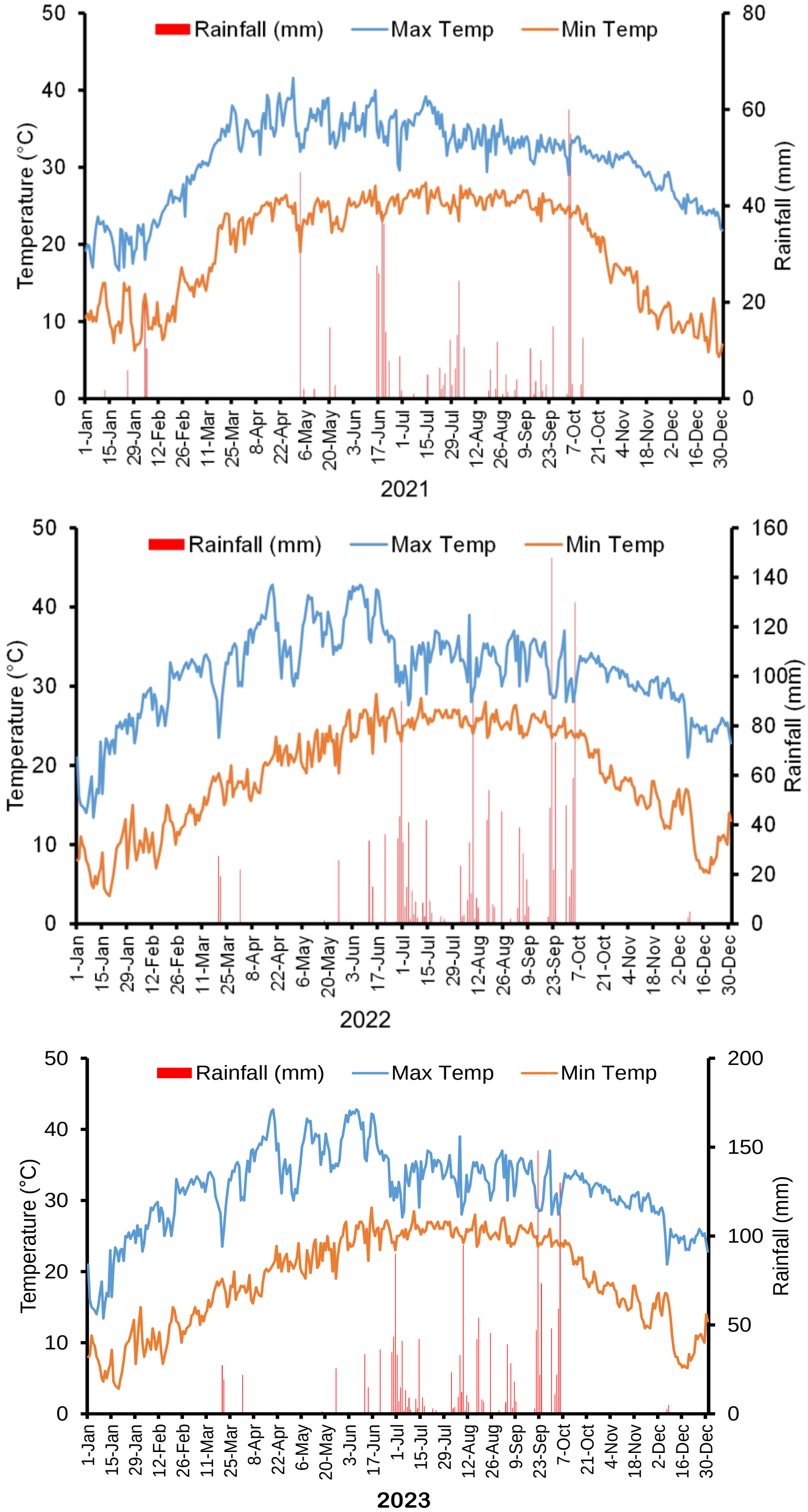

Fig. 1. Meteorological data during experimental Years 2021, 2022, 2023 (Meteorological Unit, Bihar Agricultural University)

Table 4. Effect of nutrient and pest management practices on CGR of maize

Treatment	CGR (g m^{-2} day^{-1})			
	30-60 DAS	**60-90 DAS**	**90-120 DAS**	**120-Harvesst**
N_1	7.70	14.4	22.8	12.6
N_2	6.55	14.5	19.9	10.5
N_3	8.33	15.3	23.2	12.9
N_4	9.62	14.5	23.6	13.1
N_5	7.08	14.6	21.6	11.0
N_6	9.83	14.9	24.2	14.6
N_7	6.22	13.3	18.4	9.7
SEm (±)	0.52	0.6	1.6	1.6
CD (P=0.05)	1.59	NS	4.9	4.8

Table 5. Effect of nutrient and pest management practices on total biomass production and yield of maize

Treatment	Total biomass	Stover yield	Grain Yield	Stone Yield	Harvest index (%)
	(kg ha^{-1})				
N_1	18226.67	7050.00	9030.00	2146.67	48.98
N_2	15888.00	6781.33	7313.00	1793.67	48.12
N_3	18538.99	7072.33	9163.33	2303.33	49.20
N_4	18986.00	7123.33	9376.67	2486.00	49.61
N_5	16903.67	6991.00	7903.33	2009.33	48.76
N_6	19538.33	7103.33	9896.67	2538.33	49.65
N_7	15101.67	6766.67	6670.00	1665.00	48.07
SEm (±)	426.04	74.12	88.15	30.31	0.36
CD (P=0.05)	1388.36	228.40	271.62	93.39	NS

4. CONCLUSION

Rice- maize cropping system has proved to be a productive and profitable cropping system for Eastern India and the places where, the productivity of wheat is declining day by day due to delayed wheat sowing after the late harvest of rice and also due to terminal heat stress during grain filling stage. Therefore, replacing the wheat crop with a productive and remunerative crop like maize can help in addressing the sustainability issues in a holistic manner. Thus, the results of this research contribute to the existing knowledge by providing empirical evidence that clarifies the significant impact of various input management practices on sustainable maize production. The input management practices can be an effective tool in maximizing productivity of maize, while, SPAD based N management + insecticide application Chlorpyriphos 20 EC @ 0.02% or 0.2 ml/litre of water had the better performance in all the aspect of growth parameters, yield attributing characters and yield of maize crop. It can be determined that by using SPAD meter, the farmers can improve the production level besides saving N fertilizer application rate. However, to stand up with a specific conclusion and suggestion the irrigation and weed management practices need to be incorporated under the experimentation in future.

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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