



Growth, Yield and Agronomic Efficiency of Maize (*Zea mays* L.) under Different Nitrogen Rates in Western Viti Levu, Fiji

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ABSTRACT

Background: Nitrogen deficiency has become one of the major constraints limiting maize productivity in Fiji due to continuous cropping and poor fertilizer application. However, information on optimum nitrogen requirements for maize production under Fiji's agro-climatic conditions is still limited.

Methods: A field experiment was conducted at the Sugar Research Institute of Fiji, Ba, from November 2025 to February 2026, to evaluate the effects of different nitrogen rates on maize growth, yield and agronomic efficiency. The experiment consisted of a randomized complete block design with five nitrogen rates (0, 50, 100, 150 and 200 kg N ha⁻¹) in four replications. Growth attributes, SPAD values, yield components, grain yield, biomass, harvest index and agronomic efficiency were measured and subjected to analysis of variance and regression analysis.

Result: Nitrogen application significantly ($p < 0.05$) improved plant height, leaf number, leaf area index, SPAD values, biomass production and yield attributes compared with the control. Treatment 200 kg N ha⁻¹ recorded the highest grain yield (6.88 t ha⁻¹), total biomass (19.46 t ha⁻¹), harvest index (0.35) and grains per cob (327). Agronomic efficiency was highest at 50 kg N ha⁻¹ (36.8 kg grain kg⁻¹ N) and declined with increasing nitrogen rates. A strong positive relationship ($R^2 = 0.998$) between grain yield and nitrogen application was recorded and no yield plateau was reached up to 200 kg N ha⁻¹. The results show that maize has a high nitrogen demand in Western Viti Levu and more studies are needed to determine the optimum nitrogen requirement for sustainable production in Fiji.

Key words: Agronomic efficiency, Grain yield, Maize, Nitrogen fertilization, Nitrogen use efficiency.

INTRODUCTION

Nitrogen (N) is one of the most essential plant nutrients and plays a central role in photosynthetic activity, plant growth and agricultural productivity (Gheith *et al.*, 2022). Its availability strongly influences maize growth and grain yield through effects on radiation interception, photosynthetic activity and N partitioning to reproductive organs (Sandhu *et al.*, 2021). Adequate N supply promotes leaf area development, maintains photosynthetic activity and enhances dry matter production (Kaur *et al.*, 2012; Shah *et al.*, 2022). It also contributes to improved crop productivity and nutrient use efficiency (Habtegebrail *et al.*, 2007). Previous studies have reported increases in maize grain yield of 43-68% and biomass production of 25-42% following N fertilization (Gheith *et al.*, 2022; Ogola *et al.*, 2002). In addition, N is involved in several physiological and metabolic processes that are essential for crop growth and development (Vijayalakshmi *et al.*, 2013).

Low soil nitrogen (N) availability is a common constraint in Fijian agricultural soil, which results from continuous cropping and inadequate fertilization management (Amoah *et al.*, 2025). Nitrogen deficiency limits vegetative development, leaf area expansion, chlorophyll synthesis and photosynthetic capacity, ultimately reducing maize grain yield (Zhao *et al.*, 2022). Ali and Anjum (2017) reported that insufficient nitrogen supply suppresses leaf development, decreases chlorophyll production and limits biomass accumulation. Improvement in nitrogen use efficiency is therefore important for sustainable maize

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production in Fiji, where high rainfall and associated leaching losses frequently reduce nitrogen availability.

Although numerous studies have investigated nitrogen fertilization in maize worldwide, determination of the optimal nitrogen application rate remains challenging because crop responses vary with soil properties, climatic conditions and management practices. Although fertilizer management studies on maize have been conducted in Fiji (Sachan *et al.*, 2021), field-based information specifically addressing maize response to different nitrogen rates and nitrogen-

use efficiency under local agroclimatic conditions remains limited. Consequently, fertilizer recommendations developed in other regions may not be directly applicable to Fiji. Therefore, this preliminary study aimed to evaluate the response of maize to different nitrogen application rates under the agro-climatic conditions of Western Viti Levu, Fiji. The findings provide baseline information to support future multi-location and multi-season studies for developing sustainable nitrogen management strategies for maize production in Fiji.

MATERIALS AND METHODS

Experiment

A field experiment was conducted at the Sugar Research Institute of Fiji (SRIF) farm, located in Ba, Western Viti Levu, Fiji, from November 2025 to February 2026. The study site is located at latitude 17.5454° S and longitude 177.6819° E at an elevation of approximately 79 m above sea level. The region has a tropical climate with a mean annual temperature of 26°C and annual rainfall of about 2163 mm. Before planting, composite soil samples (0-20 cm depth) were collected and analyzed for selected physicochemical properties. The soil had a pH of 6.4, organic carbon content of 2.96%, total nitrogen of 0.57%, available phosphorus of 179.9 mg kg⁻¹ and exchangeable potassium of 300.22 mg kg⁻¹. The experiment was arranged in a randomized complete block design (RCBD) with five nitrogen (N) rates and four replications. The treatments consisted of N0 (0 kg N ha⁻¹), N50 (50 kg N ha⁻¹), N100 (100 kg N ha⁻¹), N150 (150 kg N ha⁻¹) and N200 (200 kg N ha⁻¹). Each experimental plot measured 3 m × 2 m. Nitrogen was applied as urea (46% N) in two equal applications. Fifty per cent of the respective N treatment rate was applied at planting and incorporated lightly into the soil immediately after application, while the remaining 50% was applied as a top dressing at four weeks after sowing (approximately 28 days after sowing). No additional phosphorus or potassium fertilizer was applied during the experiment. The soil was characterized before planting to assess its initial nutrient status, including available phosphorus and exchangeable potassium. A commercial hybrid maize cultivar, 'Nirala', obtained from the Sigatoka Research Station of the Ministry of Agriculture, Fiji, was used. Seeds were manually sown at a spacing of 75 cm between rows and 30 cm between plants, resulting in an approximate plant population of 44,444 plants ha⁻¹. Two seeds were sown per hill and subsequently thinned to one healthy plant after 14 days. Other agronomic practices were followed as per standard procedures.

Data collection

Growth parameters

Four plants per plot were tagged for growth measurements. Plant height, number of leaves, leaf length, leaf width, stem diameter and SPAD readings were recorded monthly.

Leaf area index (LAI) was estimated by measuring leaf length and maximum leaf width using a correction factor of 0.75 and was calculated as leaf area per unit ground area. SPAD values were measured using a LEAF CHL BLUE on three fully expanded leaves per plant and averaged.

Yield and yield attributes

At physiological maturity, the two central rows of each plot were harvested to avoid border effects. Ears were manually harvested, dehusked and shelled. Grain yield was adjusted to 14% moisture content and expressed as t ha⁻¹. Yield attributes, including the number of cobs per plant, number of grains per cob, cob size and cob weight, were recorded. Stover samples were oven-dried at 70°C until constant weight and combined with grain dry weight to estimate total aboveground biomass on a hectare basis. Harvest index (HI) was calculated as the ratio of grain yield to total aboveground biomass.

Agronomic efficiency

Agronomic efficiency (AE) was calculated to assess nitrogen use efficiency using the following equation:

$$AE = \frac{(Y_n - Y_0)}{N}$$

Where,

Y_n = Grain yield at a given nitrogen rate.

Y_0 = Yield in the control treatment.

N = Amount of nitrogen applied (kg ha⁻¹) (Raun and Johnson, 1999).

Statistical analysis

Data were checked for normality and homogeneity of variance before analysis. Analysis of variance (ANOVA) was performed using Statistix 10 and the treatment means were separated using the least significant difference (LSD) test at the 5% probability level. Regression analysis was also conducted to evaluate the relationship between nitrogen application rate and grain yield. A quadratic regression model was fitted to evaluate the relationship between nitrogen rate and grain yield and describe the response of maize grain yield to increasing nitrogen rates.

RESULTS AND DISCUSSION

Growth parameters

Nitrogen application significantly influenced maize growth throughout the crop cycle (Table 1). Plant height increased progressively with increasing nitrogen rates, with the tallest plants consistently recorded at 200 kg N ha⁻¹, while the control treatment produced the shortest plants. Differences among higher nitrogen treatments were minimal during the early growth stage (30 DAS), reflecting the relatively low nutrient demand of young plants with limited biomass accumulation and root development (Lopez *et al.*, 2023). However, from 60 DAS onwards, plant height increased significantly with nitrogen application and by 90 DAS, all treatments differed significantly, with plant height ranging

from 171.3 cm in the control to 220.5 cm at 200 kg N ha⁻¹. Similar positive responses of maize height to increasing nitrogen application have been reported by Asaduzzaman *et al.* (2014) Majid *et al.* (2017) and Santo *et al.* (2026).

Nitrogen application also significantly increased the number of leaves throughout the growing period (Table 1). Nitrogen-treated plants consistently produced more leaves than the control, with the highest number of leaves (17) recorded at 200 kg N ha⁻¹ at 90 DAS. Improved leaf production under higher nitrogen levels reflects enhanced vegetative growth and canopy development resulting from increased nitrogen availability (Leghari *et al.*, 2016).

Leaf area index (LAI) increased significantly with increasing nitrogen rates at all growth stages (Table 1). The highest LAI was consistently observed at 200 kg N ha⁻¹, increasing from 2.6 at 30 DAS to 5.9 at 90 DAS, whereas the control treatment recorded the lowest values throughout the experiment. The progressive increase in LAI indicates improved canopy development and greater photosynthetic capacity under adequate nitrogen supply, which agrees with previous reports in maize (Asaduzzaman *et al.*, 2014; Ajiboye and Oroka, 2025).

Stem girth was not significantly affected by nitrogen application at any growth stage, although a gradual numerical increase was observed with increasing nitrogen rates (Table 1). The largest stem girth was recorded at 200 kg N ha⁻¹, while the control consistently produced the smallest stems. Similar observations have been reported by Hassan *et al.* (2010) suggesting that stem diameter is less responsive to nitrogen fertilization than other vegetative growth parameters.

SPAD chlorophyll readings increased significantly with increasing N application throughout the crop cycle (Table 1). The response became particularly pronounced at physiological maturity, when SPAD values increased from 35.2 in the control to 45.0, 49.6, 53.1 and 63.8 under 50, 100, 150 and 200 kg N ha⁻¹, respectively. The differences among treatments at 90 DAS exceeded the critical difference at the 5% probability level, indicating a significant effect of N availability on leaf chlorophyll status. The higher SPAD values under increased N supply suggest improved chlorophyll formation and plant N status, which may have contributed to greater photosynthetic capacity and biomass accumulation. Similar increases in SPAD values with increasing N availability have been reported in maize (Hassan *et al.*, 2010).

Yield and yield attributes

Nitrogen application significantly improved maize yield attributes (Table 2). The number of cobs per plant increased with nitrogen application, with treatments receiving 100-200 kg N ha⁻¹ producing two cobs per plant. Control and 50 kg N ha⁻¹ produced only one cob per plant. Similarly, cob length and cob diameter increased significantly with increasing nitrogen rates. The highest values were recorded at 200 kg N ha⁻¹ (16.5 cm and 3.47 cm, respectively), while

Table 1: Effect of nitrogen rates on maize (*Zea mays* L.) growth and growth attributes.

Treatments	Plant height (cm)						Leaves plant ⁻¹						LAI						Stem girth (cm)						SPAD					
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
N ₀ : Control with 0 kg N ha ⁻¹	30.1b	162.5d	171.3e	14d	13b	14d	1.2d	2.3d	2.1e	1.03a	1.06a	1.30a	1.03a	1.06a	1.30a	43.0c	38.0c	35.2e	43.0c	38.0c	35.2e	43.0c	38.0c	35.2e	43.0c	38.0c	35.2e	43.0c	38.0c	35.2e
N ₅₀ : 50 kg N ha ⁻¹	42.6a	167.9d	181.0d	14d	14a	14d	1.7c	2.9c	3.0d	1.33a	1.37a	1.54a	1.33a	1.37a	1.54a	50.6b	51.3b	45.0d	50.6b	51.3b	45.0d	50.6b	51.3b	45.0d	50.6b	51.3b	45.0d	50.6b	51.3b	45.0d
N ₁₀₀ : 100 kg N ha ⁻¹	44.6a	174.8c	187.5c	15c	14a	15c	2.1b	3.3b	3.9c	1.44a	1.53a	1.56a	1.44a	1.53a	1.56a	51.6b	61.5a	49.6c	51.6b	61.5a	49.6c	51.6b	61.5a	49.6c	51.6b	61.5a	49.6c	51.6b	61.5a	49.6c
N ₁₅₀ : 150 kg N ha ⁻¹	45.1a	182.4b	193.6b	16b	14a	16b	2.1b	3.5b	4.8b	1.55a	1.57a	1.66a	1.55a	1.57a	1.66a	52.1b	63.9a	53.1b	52.1b	63.9a	53.1b	52.1b	63.9a	53.1b	52.1b	63.9a	53.1b	52.1b	63.9a	53.1b
N ₂₀₀ : 200 kg N ha ⁻¹	48.8a	195.6a	220.5a	17a	14a	17a	2.6a	4.1a	5.9a	1.57a	1.89a	1.98a	1.57a	1.89a	1.98a	54.7a	66.0a	63.8a	54.7a	66.0a	63.8a	54.7a	66.0a	63.8a	54.7a	66.0a	63.8a	54.7a	66.0a	63.8a
SEM ±	1.97	4.11	1.85	0.45	0.41	0.45	0.15	0.24	0.12	0.54	0.55	0.41	0.54	0.55	0.41	1.73	2.99	2.39	1.73	2.99	2.39	1.73	2.99	2.39	1.73	2.99	2.39	1.73	2.99	2.39
CD (P= 0.05)	6.06	5.81	2.62	0.64	0.58	0.64	0.22	0.34	0.17	0.77	0.78	0.57	0.77	0.78	0.57	2.45	4.23	3.39	2.45	4.23	3.39	2.45	4.23	3.39	2.45	4.23	3.39	2.45	4.23	3.39

the control produced the smallest cobs (10.4 cm and 2.32 cm). The results demonstrate that adequate nitrogen promotes reproductive development, cob elongation and cob size (Leghari *et al.*, 2016; Afrida *et al.*, 2024).

Nitrogen application also significantly increased the number of grains per cob. The highest number of grains (327) per cob was recorded at 200 kg N ha⁻¹, whereas the control produced only 115 grains per cob. The increase in grains per cob with nitrogen rates may be attributed to enhanced nutrient availability that supports better pollination, kernel set and grain filling (Srivastava *et al.*, 2018; Rimmi *et al.*, 2023).

The total aboveground biomass increased significantly with increasing nitrogen application, ranging from 4.93 t ha⁻¹ in the control to 19.46 t ha⁻¹ at 200 kg N ha⁻¹. According to Galindo *et al.* (2024) and Ram *et al.* (2023), nitrogen fertilizers improve maize growth, productivity and overall plant biomass.

Harvest index was also significantly influenced by nitrogen application. The highest harvest index (0.35) was recorded at 200 kg N ha⁻¹ compared with 0.15 in the control. This indicates that higher nitrogen application improved the partitioning of assimilates towards grain production compared to lower nitrogen levels (Fan *et al.*, 2023).

The highest grain yield was recorded at 200 kg N ha⁻¹ (6.88 t ha⁻¹) and the lowest was recorded at 0 kg N ha⁻¹ (0.88 t ha⁻¹). At 0, 50 and 150 kg N ha⁻¹, significant differences of 0.88 t, 2.72 t and 4.85 t of grain yield were observed among treatments. The treatment 100 kg N ha⁻¹ recorded a similar statistical difference of 4.14 t ha⁻¹ to 150 kg N ha⁻¹. The highest grain yield at 200 kg N ha⁻¹ may be attributed to improved vegetative growth due to increased nitrogen levels, which resulted in better grain yield and production (Ali and Anjum, 2017).

Agronomic efficiency

Agronomic efficiency of Maize was highest at 50 kg N ha⁻¹ (36.8 kg grain per kg N). However, increasing nitrogen rates from 100 to 150 kg N ha⁻¹ led to a decrease in agronomic efficiency (32.6 and 26.5 kg grain per kg N), indicating reduced efficiency of nitrogen use at higher application levels (Fig 1). Similar findings have been reported in previous studies, where increasing nitrogen rates resulted in reduced agronomic efficiency due to luxury consumption and reduced nitrogen use efficiency by the plant (Raun and Johnson, 1999). A slight increase in agronomic efficiency was found at 200 kg N ha⁻¹, which may be attributed to improved nutrient availability; however, such increases can

Table 2: Effect of nitrogen rates on maize (*Zea mays* L.) yield and yield attributes.

Treatments	Cobs/plant	Cob length (cm)	Cob girth (cm)	Grains/cob	Total biomass (t ha ⁻¹)	Harvest index
N ₀ : Control with 0 kg N ha ⁻¹	1b	10.4c	2.32b	115c	4.93e	0.15c
N ₅₀ : 50 kg N ha ⁻¹	1b	11.9b	2.62b	163b	10.94d	0.25b
N ₁₀₀ : 100 kg N ha ⁻¹	2a	14.7a	2.72b	193b	14.26c	0.27b
N ₁₅₀ : 150 kg N ha ⁻¹	2a	15.8a	3.30a	295a	16.80b	0.27b
N ₂₀₀ : 200 kg N ha ⁻¹	2a	16.5a	3.47a	327a	19.46a	0.35a
SEM±	0.11	0.98	0.34	31.6	1.79	0.05
CD (0.05)	0.15	1.39	0.48	44.7	2.53	0.07

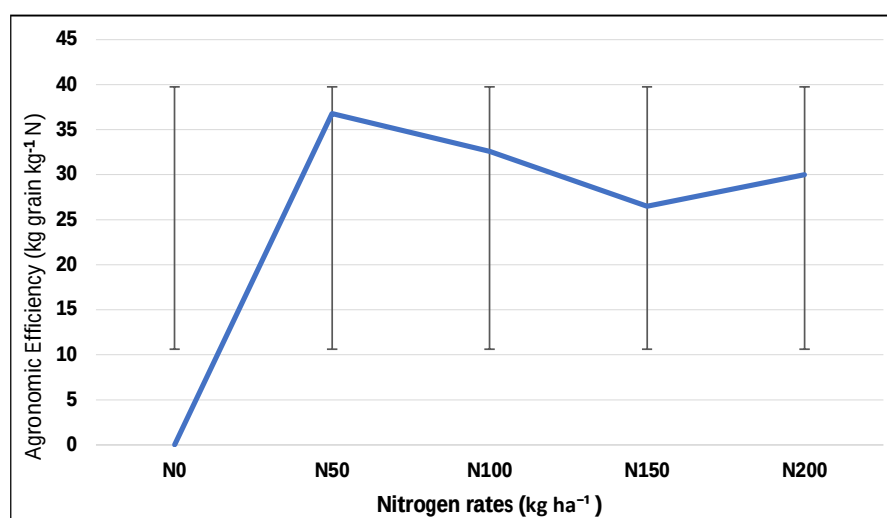


Fig 1: Agronomic efficiency of maize at different nitrogen rates.

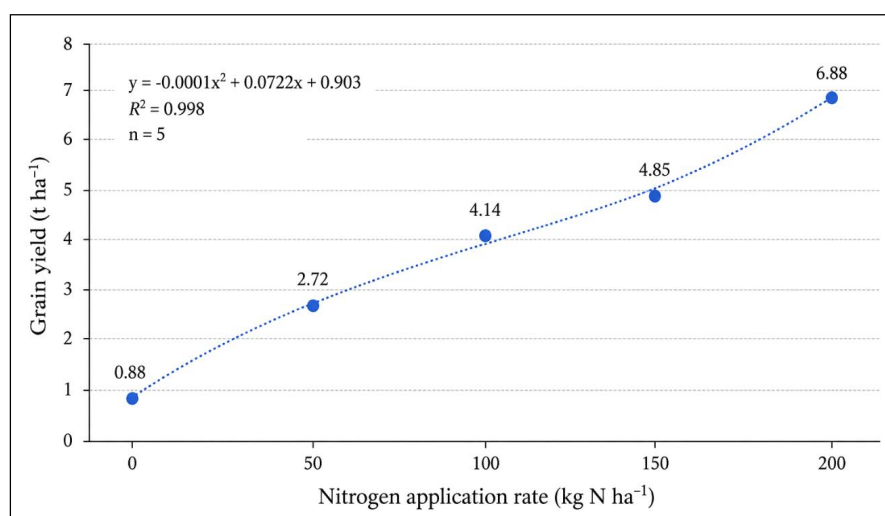


Fig 2: Relationship between nitrogen application rate and maize grain yield under the agro-climatic conditions of Western Viti Levu, Fiji.

lead to environmental losses through leaching, volatilization and denitrification (Legesse *et al.*, 2023).

Grain yield response to nitrogen application

Regression analysis revealed a positive ($R^2 = 0.998$) relationship between nitrogen application rate and maize grain yield (Fig 2). Grain yield increased progressively with increasing nitrogen rates and the fitted quadratic model adequately described the response pattern. However, grain yield continued to increase up to the highest nitrogen rate evaluated (200 kg N ha⁻¹), indicating that a yield plateau was not reached under the experimental conditions of this study. Consequently, the agronomic optimum nitrogen rate could not be reliably estimated within the range of nitrogen levels tested. The experimental soil had high initial available phosphorus (179.9 mg kg⁻¹) and exchangeable potassium (300.22 mg kg⁻¹), indicating a substantial indigenous supply of these nutrients under the prevailing soil conditions. Consequently, the observed treatment responses were primarily associated with differences in N supply within the existing soil fertility status. Nevertheless, the absence of uniform supplemental P and K may limit the applicability of these findings to soils with lower P and K availability. Future studies should evaluate maize responses to N under balanced and recommended N-P-K nutrient management.

Although the highest grain yield was obtained at 200 kg N ha⁻¹, it is important to consider nitrogen use efficiency (NUE) and environmental sustainability (Sandhu *et al.*, 2021; Karthik *et al.*, 2022). Previous studies have shown that beyond optimal levels, increased nitrogen application results in diminishing returns and greater environmental risks such as nitrate leaching and greenhouse gas emissions (Raun and Johnson, 1999; Mueller *et al.*, 2012). Yield gains between 150 and 200 kg N ha⁻¹ were recorded, relatively smaller compared to earlier increments. This suggests that 150 kg N ha⁻¹ may represent a more efficient and environmentally sustainable

rate under the given conditions. Although grain yield increased with nitrogen application, agronomic efficiency declined at higher nitrogen rates, indicating diminishing returns from additional nitrogen input. Similar reductions in nitrogen use efficiency at high nitrogen rates have been reported by Ciampitti and Vyn (2013), reflecting lower nitrogen uptake efficiency and greater nitrogen losses.

CONCLUSION

Nitrogen application significantly improved maize growth, biomass and grain yield. Although the highest yield (6.88 t ha⁻¹) was obtained at 200 kg N ha⁻¹, agronomic efficiency declined with increasing nitrogen rate. Results also indicated that the agronomic optimum nitrogen rate was not reached under the conditions of this study. However, considering both yield performance and nitrogen use efficiency, the nitrogen range of 150-200 kg N ha⁻¹ may represent a practical and agronomically effective window under the present conditions. These findings should be considered preliminary and site-specific, requiring further multi-location and multi-season studies involving a wider range of nitrogen rates before definitive nitrogen fertilizer recommendations can be developed for sustainable maize production in Fiji.

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Disclaimers

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Conflict of interest

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