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Effects of Nitrogen Fertilizer Rates on Yield and Yield Components 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

Maize is one of the most important cereal crops in the world. To investigate the effects of nitrogen fertilizer rates on growth and yield of maize and to determine the suitable nitrogen fertilizer rate, an experiment was conducted by using Randomized complete block design (RCBD) with four replications at Shwe Baho village, Zayarthiri Township, Nay Pyi Taw in post monsoon season and monsoon season. The treatments were T_1 (no nitrogen application), T_2 (90 kg N ha^{-1}), T_3 (120 kg N ha^{-1}), T_4 (150 kg N ha^{-1}) and T_5 (180 kg N ha^{-1}) treatments. The tested maize variety was pacific-789 hybrid. According to the results, application of nitrogen gave the significant effect on grain yield and yield components of maize in both seasons. The superior maize yield was observed in all

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nitrogen treatments compared to control. The use of the highest nitrogen fertilizer rate (180 kg N ha^{-1}) in T_5 gave the significant highest grain yield (7696.6 kg ha^{-1}) in post monsoon season and (8764.5 kg ha^{-1}) in monsoon season, respectively. In both seasons, the grain yield in T_5 treatment was significantly increased about 62% over T_1 treatment. Therefore, the application of nitrogen with the rate of T_5 (180 kg ha^{-1}) might be the appropriate rate to maximize the maize production. Considering the increased grain yield of the hybrid maize, nitrogen rate of T_5 (180 kg ha^{-1}) could be achieved in this study area.

Keywords: Hybrid maize; nitrogen rates; yield and yield components.

1. INTRODUCTION

Maize is the principal grain crop grown in Myanmar and a key commodity for both foreign exchange earnings and farmer income. As the primary feed crop in Myanmar, maize is the second most significant cereal crop after rice [1]. As the first grain crop to be grown worldwide, maize (*Zea mays* L.) produced 1,125 million tons, or more than 40% of all grain produced. Hungary, the third-largest producer of the crop in Europe, produced 8.4 million tons of maize in 2020, accounting for nearly 12% of the total production of 67.8 million tons [2]. Maize growing area in Myanmar was cultivated around 0.56 million ha in 2020-2021 [3]. Maize growing locations are Shan State, Chin State, Kayin State, Sagaing, Mandalay, Nay Pyi Taw, Ayeyarwady and Magway Region. Small-scale farmers are the primary producers of maize in tropical nations [4]. The production of maize increased from 1485 MT in 2011 to 2106 MT in 2021 [3]. The maize exported about 2.6 million MT [3]. In Myanmar, maize is grown for human food, animal feed for raising cattle, and a significant export commodity. Nitrogen is essential to many major processes involved in the growth and development of maize crops, it is a highly significant component of fertilizers [5]. As a main nutrient, nitrogen (N) is essential for increasing growth and higher biomass yields. It directly influences the amino acid composition of protein and thereby nutritional quality of the economic produce [6]. Maize yield is significantly influenced by the timing of N application [7]. Due to its large role in the growth and development of the maize crop, nitrogen (N) is a very important ingredient [5]. The growth, development, and grain production of maize are significantly influenced by the applications of inorganic fertilizers [8]. Thus, the present study initiated to investigate the effects of nitrogen fertilizer rates on growth and yield of maize and to determine the suitable nitrogen fertilizer rate to increase maize production in this study area.

2. MATERIALS AND METHODS

The field experiment was carried out from December to April (post monsoon season), 2022-2023 and from May to September (monsoon season), 2023. Both field experiments were conducted at Shwe Baho village, Zayarthiri Township and Nay Pyi Taw. In both seasons, the five treatments were assigned on the same size of plots with four replications. Total numbers of the experimental plots were 20 plots and each plot size was 4 m x 5 m. Spacing 75 cm x 22.5 cm between blocks and 1 m between plots were used. The tested maize variety was pacific-789 hybrid maize variety with 120 days duration. Phosphorus fertilizer was applied at 125 kg P_2O_5 ha^{-1} and Potassium fertilizer 63 kg K_2O ha^{-1} was applied at basal in all treatments. Treatments were assigned as Table 1. Before conducting the experiment, the soil sample was randomly collected to investigate some physicochemical properties. The results are shown in Table 2.

Table 1. Treatments of the experiment in both seasons

Treatments	Basal (kg N ha^{-1})	20 Days After Sowing (kg N ha^{-1})	40 Days After Sowing (kg N ha^{-1})
T_1	-	-	-
T_2 (Three equally splits)	30	30	30
T_3 (Three equally splits)	40	40	40
T_4 (Three equally splits)	50	50	50
T_5 (Three equally splits)	60	60	60

Note. Urea was used as N fertilizer

Table 2. Physicochemical properties of the experimental soils before sowing at Shwe Baho Village, Zayarthiri Township, Nay Pyi Taw

Parameters	Analytical Result	Description	Analytical Methods
Texture class	**Loamy sand**	**Sand 84.82%, Silt 7.43% and Clay 7.75%**	**Pipette method**
pH	6.24	Slightly acid	1:5 (soil: water) pH meter
Organic matter (%)	1.24	Low	Walkley-Black Method
Available N (mg kg^{-1})	69	Medium	Alkaline permanganate method
Available P (mg kg^{-1})	19	Medium	9C-Olsen's P-Malachite green
Available K (mg kg^{-1})	94	Low	15AI-1N Ammonium acetate extraction
Total N (%)	0.07	Low	Kjaldehl distillation method

2.1 Data Collection

Agronomic traits such plant height (cm), and SPAD reading were measured and the average was noted. Measuring plant height and SPAD readings as five randomly chosen plants from each plot were done at 15-day intervals. Yield components of maize such as ear height (cm), ear length (cm), ear diameter (cm), row length (cm), number of rows ear^{-1}, number of ears $plant^{-1}$, number of kernels row^{-1},1000 grain weight (g), shelling (%) and five ears grain yield were recorded from five sample plants of each plot at harvest. The grain moisture was measured by moisture sensor, moisture content was adjusted as 15%. The two rows grain yield from selected random plant of each plot were weighted and converted to t ha^{-1}.

2.2 Statistical Analysis

All experimental data were analyzed by using the Analysis of Variance (ANOVA) with Statistix-8 software. The differences in treatment means were separated by Least Significant Difference (LSD) at 5 % level.

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

Plant height in all treatments increased progressively from 15 DAS to 75 DAS under both seasons (Fig. 1). It was found that only control treatment (T_1) gave the minimum plant height at all growth stages, while three equally splits of N fertilizer application (T_5) possessed a highly significant difference in plant height among the other treatments similarly [9]. discovered that higher doses of nitrogen application resulted in taller maize plants. Higher nitrogen application rates result in increased maize growth and growth characteristics [10]. The right explanation was provided by the statement that supplying N in the right amounts could improve plant heights and increase plant reactivity to better use of other inputs than supplying the entire N at sowing time. In this study, N was applied at three equally splits (at basal, 20 DAS and 40 DAS.

3.2 SPAD Readings

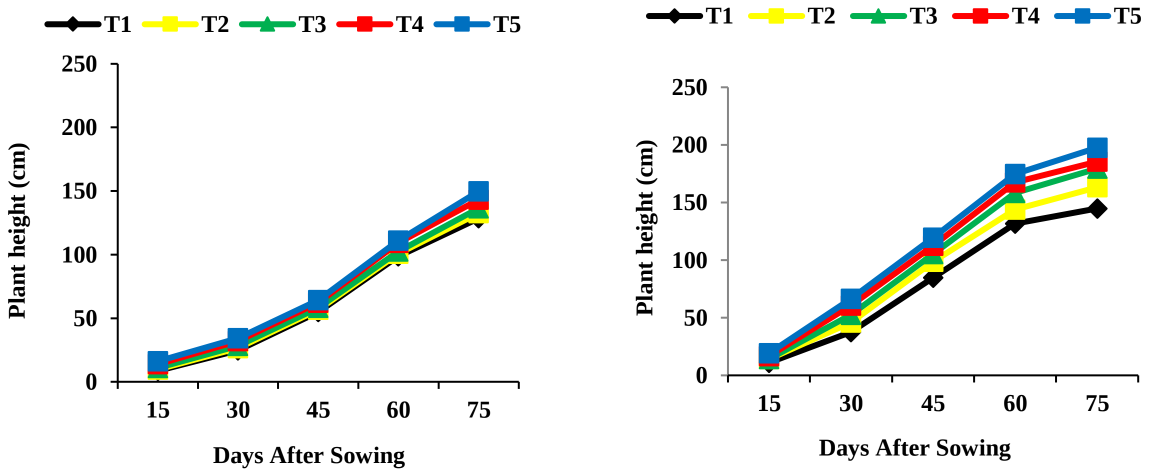
The chlorophyll meter is a tool that can be used to evaluate crop N status and perhaps improve N use efficiency. SPAD readings in all treatments increased progressively from 15 DAS to 75 DAS under both seasons (Fig. 2). It was revealed that only control treatment (T_1) gave the minimum SPAD reading at all growth stages, while three equally splits of N fertilizer application (T_5) possessed significant difference in SPAD readings among the other treatments similarly. The leaf N concentration and SPAD values could predict the need for N top dressing at specific growth stages [11]. Maize's chlorophyll content has a positive and significant effect on grain yield [12]. In this study, maize leaves at different ages had considerably different SPAD values before and after anthesis. The results of the correlation indicated a significant positive association between grain yield and various stages of SPAD values (Fig. 2).

3.3 Ear Height (cm)

In post monsoon season, we observed a significant difference in the ear height of maize plants; T_5 had the greatest value (100.33 cm). The values of T_1 (77.98 cm), T_2 (85.09 cm), T_3 (88.27 cm), and T_4 (88.27 cm) for the ear height (cm) of the other treatments were significantly different. Significant impacts of nitrogen fertilizer were also found in ear height; T_5 gave the highest values (100.33 cm), whereas T_1 produced the lowest values (77.98 cm). In monsoon season, a significantly significant difference in the ear height of maize plants; T_5 had the greatest value, (113.16 cm). The values of T_1 (83.82 cm), T_2 (88.52 cm), T_3 (94.74 cm), and T_4 (100.33 cm) for the ear height (cm) were significantly different. Significant impacts of nitrogen fertilizer were given in ear height. T_5 recorded the highest values (113.16 cm), whereas T_1 produced the lowest values (83.82 cm).

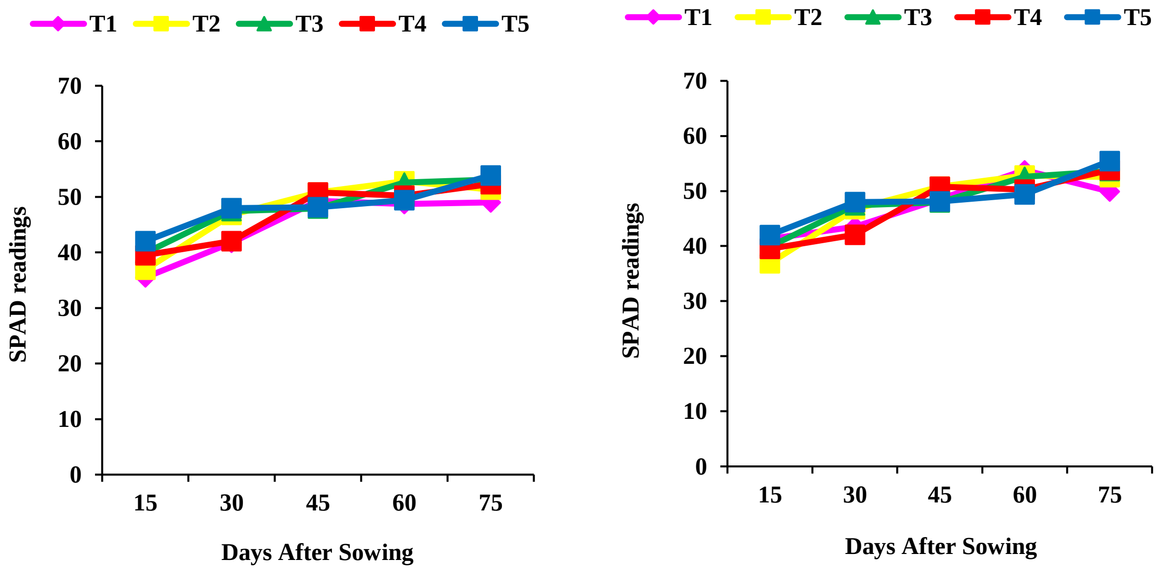
3.4 Ear Length (cm)

In both seasons, the longest ear length was measured from T_5 treatment. The results demonstrated that ear length increased with the increase in nitrogen level from T_5. When nitrogen fertilizer was administered in three equally splits (basal, 20 DAS and 40 DAS), the longer ears length was obtained than control. Maize ear length is a significant agronomic feature that is directly correlated with total grain output [13].



(a) Post monsoon season **(b) Monsoon season**

Fig. 1. Mean values of plant height as affected by different rates of nitrogen fertilizer application in post monsoon and monsoon seasons, 2022-2023



(a) Post monsoon season **(b) Monsoon season**

Fig. 2. Mean values of SPAD readings as affected by different rates of nitrogen fertilizer application in post monsoon and monsoon seasons, 2022-2023

Table 3. Mean values of ear height (cm), ear length (cm) and ear diameter (cm) as affected by different rates of nitrogen fertilizer application in post monsoon and monsoon seasons, 2022-2023

Treatments	Ear height (cm)		Ear length (cm)		Ear diameter (cm)	
	Post monsoon season	monsoon season	Post monsoon season	monsoon season	Post monsoon season	monsoon season
T_1 (Control)	77.98 d	83.82 d	19.38	19.63	4.75	4.68
T_2 (90 kg N ha^{-1})	85.09 c	88.52 d	20.25	20.25	4.78	4.70
T_3 (120 kg N ha^{-1})	88.27 b	94.74 c	19.88	19.88	4.68	4.63
T_4 (150 kg N ha^{-1})	88.27 b	100.33 b	20.25	19.75	4.88	4.50
T_5 (180 kg N ha^{-1})	100.33 a	113.16 a	20.75	20.25	4.75	4.75
$LSD_{0.05}$	**2.98**	**5.11**	**1.38**	**0.96**	**0.44**	**0.19**
Pr>F	**	**	**ns**	**ns**	**ns**	**ns**
CV%	**2.20**	**3.45**	**4.46**	**3.13**	**6.05**	**6.08**

*In each column, means followed by a different letter are significantly different at the ns non-significant difference, **significant difference at 1% level*

Table 4. Mean values of row length (cm), number of ears plant $^{-1}$ and number of kernels row^{-1} as affected by different rates of nitrogen fertilizer application in post monsoon and monsoon seasons, 2022-2023

Treatments	Row length (cm)		Number of earsplant $^{-1}$		Number of kernels row^{-1}	
	Post monsoon season	monsoon season	Post monsoon season	monsoon season	Post monsoon season	monsoon season
T_1 (Control)	19.38	20.25	1.00 d	1.00 d	37.75 b	38.50 b
T_2 (90 kg N ha^{-1})	20.13	20.63	1.08 c	1.08 c	40.00 a	40.75 b
T_3 (120 kg N ha^{-1})	19.88	19.88	1.13 bc	1.13 bc	40.50 a	39.50 b
T_4 (150 kg N ha^{-1})	20.25	20.50	1.15 b	1.18 b	41.00 a	41.50 ab
T_5 (180 kg N ha^{-1})	20.75	21.00	1.23 a	1.25a	41.50 a	44.25 a
$LSD_{0.05}$	**1.43**	**1.47**	**0.05**	**0.05**	**1.83**	**2.81**
Pr>F	**ns**	**ns**	**	**	*	*
CV%	**4.62**	**4.68**	**3.17**	**3.14**	**2.96**	**4.48**

*In each column, means followed by a different letter are significantly different at the ns non-significant difference, *significant difference at 5% level, **significant difference at 1% level*

Table 5. Mean values of 1000 grain weight (g), grain yield (kg ha^{-1}) and shelling % as affected by different rates of nitrogen fertilizer application in post monsoon and monsoon seasons, 2022-2023

Treatments	1000 grain weight (g)		Grain yield (kg ha^{-1})		Shelling (%)	
	Post monsoon season	monsoon season	Post monsoon season	monsoon season	Post monsoon season	monsoon season
T_1 (Control)	360.0 d	397.5 d	4747.9 e	5409.3 e	84 b	84 c
T_2 (90 kg N ha^{-1})	405.0 c	440.0 c	5603.6 d	6310.8 d	85 b	86 b
T_3 (120 kg N ha^{-1})	425.0 bc	465.0 b	6522.2 c	6885.6 c	85 b	86 b
T_4 (150 kg N ha^{-1})	450.0 b	475.0 ab	7248.3 b	7632.9 b	85 b	86 b
T_5 (180 kg N ha^{-1})	480.0 a	495.0 a	7696.6 a	8764.5 a	87 a	88 a
$LSD_{0.05}$	**28.27**	**23.87**	**442.58**	**338.46**	**1.39**	**0.95**
Pr>F	**	**	**	**	**	**
CV%	**4.33**	**3.38**	**4.51**	**3.14**	**1.06**	**0.72**

*In each column, means followed by a different letter are significantly different at the **significant difference at 1% level*

3.5 Ear Diameter (cm)

The analysis of variance showed that, the effect of all treatments on ear diameter was not significant. In post monsoon season, the highest ear diameter was obtained from T_4 treatment and in monsoon season, the highest ear diameter was obtained from T_5 treatment. The other treatments yielded somewhat lower but similar ear diameter values. However, some researchers reported different results and they found that the nitrogen fertilizer application increased the ear diameter values [14].

3.6 Number of Ears Plant^{-1}

The mean number of ears plant^{-1} was calculated by counting all the ears in each plot and dividing the total by the number of plants in each plot. Furthermore, the greatest yield of maize grains were obtained by applying 180 kg N ha^{-1} in three equally divided applications at baseline, 20 days after sowing, and 40 days after sowing [15].

3.7 Number of Kernels Row^{-1}

In post monsoon season, there was a noticeable variation in the number of kernels row^{-1} across all treatments, with the exception of the T_1 (control) treatment, which showed the minimum number of kernels row^{-1}. Significant differences were found in T_5 giving the maximum number of kernels row^{-1} during the monsoon season.

3.8 1000 Grain Weight (g)

1000 grain weight (g) were shown in Table 5. At the 1% level ($P<0.01$) in both seasons, there were highly significant differences among all treatments. However, the T_5 treatment produced the largest 1000 grain weight (g) while the T_1 treatment produced the lowest 1000 grain weight (g).

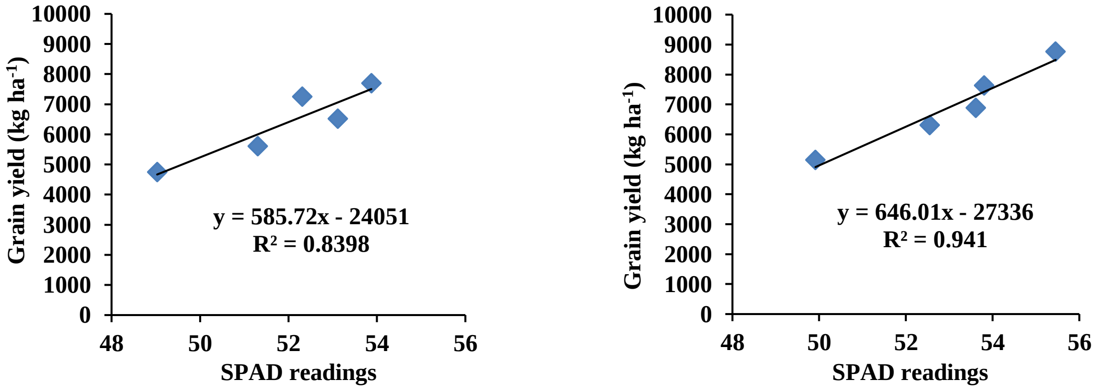
3.9 Shelling Percent

Table 5 showed mean values for shelling percent which were affected by different rates of nitrogen fertilizer application in both seasons. There were highly significant differences in all treatments. The highest shelling percent (78% and 88%) was obtained at T_5 treatment in post monsoon and monsoon seasons. The lowest shelling percent was resulted at T_1 treatment.

3.10 Grain Yield (kg ha^{-1})

The results of the maize grain production (kg ha^{-1}) for both seasons as a function of different nitrogen fertilizer application rates are shown in Table 5. The difference in grain yield between the two seasons was particularly apparent. The T_5 treatment produced the highest grain yield (7696.6 kg ha^{-1}) with highly significant difference at 1% level, in post monsoon season, while the T_1 treatment produced the lowest grain yield (4747.9 kg ha^{-1}). The T_5 treatment produced the highest grain yield (8764.5 kg ha^{-1}) with highly significant difference at the 1% level, in the monsoon season, while the T_1 treatment produced the lowest grain yield (5409.3 kg ha^{-1}). The yield of maize grains increased in tandem with an increase in the N level [16]. Many authors including, have reported that increased N rates improves maize grain yield [17].

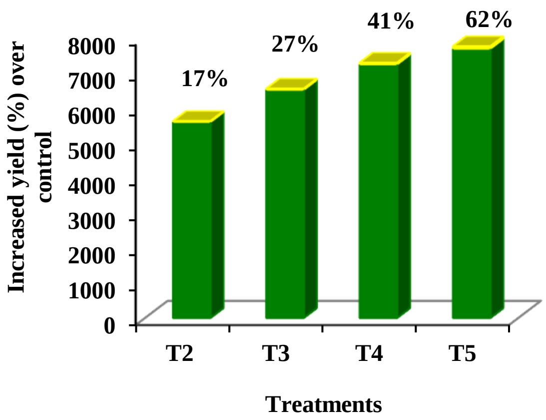
3.11 Relationship between SPAD Readings and Grain Yield (kg ha^{-1}) of Maize in Post Monsoon and Monsoon Seasons, 2022-2023



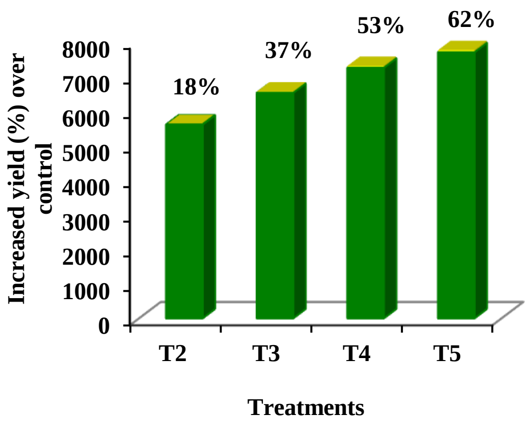
(a) Post monsoon season **b. Monsoon season**

Fig. 3. Relationship between SPAD readings and grain yield (kg ha^{-1}) as affected by different rates of nitrogen fertilizer application in post monsoon and monsoon seasons, 2022-2023

3.12 Increased Yield (%) over Control as Affected by Different Rates of Nitrogen Fertilizer Application in Post Monsoon and Monsoon Seasons, 2022-2023



(a) Post monsoon season



b. Monsoon season

Fig. 4. Mean values of increased yield (%) over control as affected by different rates of nitrogen fertilizer application in post monsoon and monsoon seasons, 2022-2023

4. CONCLUSION

In both seasons, T_5 (180 kg N ha^{-1}) gave the highest values for plant height, SPAD readings, number of ear $plant^{-1}$, ear height, ear length, ear diameter, row length, number of kernels row^{-1}, number of rows ear^{-1}, 1000 grain weight, shelling % and grain yield. It increasing nitrogen rate significantly enhanced the growth and yield parameters of pacific-789 hybrid maize variety. Considering the increased seed yield of the cultivar (pacific-789) hybrid maize, nitrogen rate of 180 kg N ha^{-1} is recommended to could be achieve the highest grain yield for both seasons this study area.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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