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Original Research

Effects of Different Nitrogen Fertilizer Rates on the Vegetative Growth of Maize (*Zea mays* L.)

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Abstract

A field experiment was conducted at Wollega University, College of Agriculture, on a farm designated for experimental research. *The study aimed to assess the effect of varying nitrogen* rates *on the vegetative growth of maize. The total experimental area was 11 x 6.5 m (71.5 m^2) and the size of each plot was 1.25 x 3 m (3.75 m^2). The variety of maize (BH 140) was combined with four nitrogen rates (*0, 60, 175, and 250 kg per hectare)*, and the field experiment was arranged in a randomized complete block design and replicated three times. The treatment was assigned to the experimental plot in a random method. Five plants from each plot's two middle rows provided for data collections (percentage of emerged seedlings, number of leaves per plant, plant height, and leaf area per plant). The collected data were analyzed by SAS software. The main effect of nitrogen fertilizer rates was significantly ($p < 0.05$) influenced on the leaf length, plant height, number of leaves per plant, and leaf area per plant, while plant height showed a highly significant effect ($p < 0.01$). However, nitrogen fertilizer rates were non-significant ($p > 0.05$) on the percentage of emerged seedlings. Thus, this study concludes that further* investigations are necessary to *determine the effect of nitrogen rates on maize growth parameters* across different sites, with careful attention to the entire growing season. *However, based on our results, we recommend 175 kg/ha of nitrogen fertilizer for maize production under the study area and similar agroecologies.*

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INTRODUCTION

Maize (*Zea mays* L.) is originated in Central America, particularly southern Mexico, and was cultivated more than 9,000 years ago (Ranere *et al*., 2009). Although introduced to Africa relatively recently compared to its long history in the Americas, historical accounts suggest maize may have been present in regions such as Nigeria before the Columbian exchange, indicating complex and possibly early routes of introduction (McCann, 2005). After its introduction to Europe in 1493, maize spread rapidly across Africa via trade and colonial networks.

In Ethiopia, maize has been used as a staple food crop in the country, especially for the livelihoods of rural communities. Its importance is attributed to its adaptability to diverse agroecological zones, high caloric content, and multiple end uses, including traditional dishes, local beverages, and processed food products (Abate *et al*., 2015). Due to its nutritional value and high-yielding potential, maize has been prioritized by the Ethiopian government through research investments and the dissemination of improved technologies.

Nutritionally, maize grain consists primarily of carbohydrates, mainly starch (60–80%), along with moderate levels of protein (8–15%), lipids concentrated in the germ, and essential minerals (Boyer & Shannon, 1987; Nuss & Tanumihardjo, 2010). Its protective husks aid in minimizing post-harvest losses, while the crop's storability and wide genetic diversity in maturity periods enhance its utility across varying farming systems (Kumar and Kalita, 2017).

Despite its importance, maize production in Ethiopia remains constrained by several abiotic and a biotic factor. Biotic factors include insect pests, diseases, nematodes, & vertebrate pests, while a biotic constraints encompass drought, salinity, extreme temperatures, nutrient deficiencies, and soil degradation (Bänziger *et al*., 2000; Cairns *et al*., 2013). These stressors, individually or in combination, reduce maize growth and yield potential. Notably, nutrient availability. particularly nitrogen is among the most preventive a biotic factor affecting maize productivity in Ethiopia (Licen *et al*., 2025).

Nitrogen is a vital macronutrient that supports key physiological processes including chlorophyll synthesis, leaf expansion, and grain filling. However, in many maize-growing regions, including Ethiopia, nitrogen fertilizer use is limited due to high costs and suboptimal application practices. Farmers often neglect basal applications or apply insufficient quantities of nitrogen fertilizers, resulting in poor yield responses (Negassa *et al*., 2007; Vos *et al*., 2025).

Currently, the national average maize yields in Ethiopia are approximately 3.3 t/ha, significantly lower than the average global yield. Low yields are often associated with limited access to improved varieties, inappropriate plant density, weed competition, poor field management, and, critically, nitrogen deficiency. Maize agronomy has been broadly studied; region-specific data on the impact of nitrogen rates on growth and yield remain insufficient.

Therefore, this study was to assess how various nitrogen application rates affected the production and growth characteristics of maize. The results are intended to guide better nitrogen management techniques for increased maize yield in the context of regional agroecological circumstances.

MATERIALS AND METHODS

Description of the Area

This research was carried out at Wollega University, **on a designated** Gimbi Campus Agricultural research site. Gimbi town is found in the west Wollaga Zone, Oromia regional state, in the western part of Ethiopia, and is located at 441 km west of Addis Ababa.

Topography

Gimbi campus Agriculture experimental site is located between 1845 and 1930 meters above sea level, with a latitude of 9°10′N and a longitude of 35°50′E**.**

Climate

The climate of Gimbi is humid subtropical. The average temperature is in the range of 19°C to 25°C, though it can occasionally fall to 12°C or raise to 35°C. About 2711 mm of precipitation falls on average each year, with 184 wet days receiving at least 1 mm (0.04 inches) of precipitation. Gimbi experiences 3804 hours of sunshine annually on average, with daylight lasting between 11 to 12 hours and 38 minutes per day.

Experimental Materials

A maize variety of (BH140) seeds were used with different levels of nitrogen fertilizer (urea). Maize seeds and urea fertilizers were obtained from Wollega University, Gimbi Campus**.** The variety is widely cultivated in various agroclimatic conditions, including the study site.

Treatments and Experimental Design

A single factory field experiment consist of four nitrogen fertilizer rates (0. 60, 175, and 250 kg/ha). The experiment was arranged in a Randomized Complete Block Design and replicated three times. The total plot size was 11 x 6.5 m (71.5 m²). A one-meter distance was maintained between replications and 0.5 meters between plots. The experiment had 12 plots, with each plot measuring 1.25 m x 3 m. A 0.75-meter distance was maintained between rows, and 0.25 meters was kept between plants. Each plot contained four rows, with five plants per row, resulting in a total of 20 plants per plot.

Nitrogen was applied in split doses: the first half was applied at the planting dates, and the remaining half was applied when the plants reached knee-height (Table 1). The treatments and nitrogen levels in each replication were as follows:

Table 1. Nitrogen levels applied for each treatment

Treatment numbers	Nitrogen level for Trt (gm/plot)	Nitrogen Levels (kg/ha)
T 1	0	0
T 2	22.5	60
T3	65.63	175
T4	181.75	250

The Collected Data

The key vegetative parameters were measured to assess the effect of different nitrogen levels on the growth and development of maize. These parameters include: percentage of emerged seedlings (%); plant height (cm); Leaf area (cm²); leaf length (cm); above-ground plant height after two month (cm). All of the above parameters were measured and recorded from five plants in the two middle rows of each plot after two months.

Method of Data Collection

Vegetative parameters (above ground) were measured from five plants randomly sampled from the middle rows of each plot.

Percentage of emerged seed: Each plot's emerged seedlings were determined by counting the number of seeds that germinated, dividing that number by the total number of seeds sowed, and then multiplying the result by 100.

Plant Height (cm): Measured from the ground level to the highest growth point above ground, once the plants reached their maximum vegetative stage.

Leaf Area (cm²): The length and width of the leaves from the middle row were measured, and their average was taken. The leaf area was then calculated using a correction factor of **0.75 cm**.

Number of Leaves: The number of leaves on five randomly selected plants was counted from each plant, and the average was calculated.

Leaf Length after Two Months (cm): Measured from the end of the sheath to the tip of the leaf. The measurement was taken from the middle of the leaf on five randomly selected plants from the two middle rows of each plot, and the average was calculated.

Data Analysis

Data were analyzed using Analysis of Variance (ANOVA) based on a Randomized Complete Block Design (RCBD) to evaluate the effects of different nitrogen levels on percentage of emerged seedlings, number of leaves per plant, leaf length, plant height, and leaf area per plant in maize. The data collected was analyzed by using the Statistical procedures Gomez and Gomez. statistically the software SAS 9.2 version. When the ANOVA showed a significant difference, treatment means were compared using the Least Significant Difference (LSD) test at 1% and 5% probability levels.

RESULTS AND DISCUSSION

The vegetative growth of maize is affected by various factors, both independently and interactively. Among these, nutrient availability. particularly nitrogen, is a primary determinant of growth performance. In this study, the individual effects of nitrogen application on key vegetative growth parameters were evaluated. The traits assessed included percentage of emergence seedlings, number of leaves per plant, leaf length, plant height, and leaf area per plant. The mean square values derived from the analysis of variance (ANOVA) for these parameters are presented in Table 2.

Table 2. Mean squares for the percentage of seedling emergence, the number of leaves per plant, leaf length, and plant height.

		Mean Square				
Source	**df**	**SE (%)**	**N L/P**	**LL**	**PH**	**LA/P**
Replication	2	0.085ns	2.25*	45.60*	83.67**	11,624.85**
Trt	3	0.223ns	1.10*	212.48*	129.83**	82,652.38**
Error	6	0.638	3.14	53.49	108	13712.18
CV(%)		1.06	4.94	3.21	4.15	13.17
LSD at 5%		2.91	3.55	18.22	20.76	354.3

ns = non-significant SE % = percentage of seedling emerge
*= significance NL/P=Number of leave per plant
** = highly significance PH=Plant height
df = degree freedom LA/P=Leaf area per plant
Trt=Treatment LL=leave length,

Percentage (%) of emerged seedlings

The application of nitrogen fertilizer rates had no statistically significant effect ($p > 0.05$) on the emerged seedlings of the maize crop, as indicated in Table 3.

Table 3. The main effect of nitrogen fertilizer rates on emerged seedlings

	Nitrogen level (kg/ha)				
	0	60	175	250	Mean
ES	96.66	98.33	100	98.33	98.33

LSD (0.05) = ns
CV (%) =1.06

According to the results of this investigation, increasing nitrogen application levels did not significantly affect the emerged seedling percentage on the maize plants. These findings contrast with the report of Uhart and Andrade (1995), who indicated that both excessive and insufficient nitrogen supply can adversely affect early crop establishment by causing delayed germination, chlorosis, leaf desiccation, and overall plant damage.

Number of leaves per plant

The application of nitrogen had a significant effect ($p < 0.05$) on the number of leaves per plant, as shown in Table 4.

Table.4 Mean number of leaves per plant as influenced by nitrogen levels

	Nitrogen levels (kg/ha)				
Parameter	0	60	175	250	Mean
NL/P	5.83b	7.80ab	10.03a	9.06a	8.18

LSD (0.05) =3.55
CV (%) = 4.94

The nitrogen application had a significant ($p < 0.05$) effect on number of leaves per plant on the above Table 4. The highest mean value (10.03 leaves per plant) was recorded at the nitrogen application rates of 175 kg/ha, while, the lowest number of leaves per plant was observed under (0 kg/ha), likely due to nitrogen deficiency. Treatment with 50 kg/ha nitrogen resulted in a higher leaf count than zero kilo gram per hectares, reflecting a positive response to nitrogen, albeit at a suboptimal rate. The application of 175 kg/ha (treatment three) produced the greatest number of leaves, indicating that this level provided an optimal nitrogen supply for vegetative development. In contrast, the treatment with 200 kg/ha (treatment four) resulted in a reduced number of leaves compared to 175 kg/ha, possibly due to the adverse effects of excessive nitrogen application. However statically non significance difference among treatment three and four.

The current result is consistent with the report by Si *et al*. (2020), who observed that increasing nitrogen rates generally enhanced leaf production per plant, with the highest values recorded at optimal nitrogen levels. However, they also noted that excessive nitrogen can lead to leaf burn and desiccation, which may reduce the number of functional leaves per plant

Leaf area per plant

The application of nitrogen had a highly significant effect on leaf area per plant ($p < 0.01$), as presented in Table 5.

Table 5. Mean leaf area per plant of the maize crop as influenced by nitrogen level.

	Nitrogen levels kg/ha				
Parameter	0	60	175	250	Mean
LA/P	494.78b	673.37ab	871.42a	562.07ab	650.50

LSD I(0.05)= 354.30
CV (%)=13.17

With respect to leaf area, the highest leaf area per plant (871.42cm^2) leaf area was recorded with the application of 175 kg/ha of nitrogen fertilizer on maize plant, while the lowest leaf area (494.78 cm^2) was recorded with the application of 0kg/ha of nitrogen. In this result, treatment one was also the lowest leaf area per plant as compared to other treatment because of nitrogen did not apply to it. Treatment two was better than the former and low leaf area per plant was obtained than treatment three, and this treatment was giving best leaf area per plant than all the other. Whereas, leaf area per plant was start to decline under treatment four, this is attributed to excess application nitrogen level. This finding was agreement with Uhart and Andrane (1995) who reported that excess supply of nitrogen could burn plant tissues and photosynthesis not properly syntheses. . These finding indicated that shortage of nitrogen fertilizer shown thin leaf, short and pale green color as a result leaf area per plant on maize plants were reduced. .

Plant height after two months

Nitrogen application had non-significant effect ($p > 0.05$) on the plant height of the maize crop, as shown in Table 6.

Table 6: The effect of nitrogen rates on plant height

	Nitrogen level (kg/ha)				
Parameter	0	60	175	250	Mean
PH (cm)	55.73a	66.87a	69.40a	58.33a	62.58

LSD (0.05) =20.76
CV (%) = 4.15

Statically, different rates of nitrogen fertilizer application did not show significant difference on plant height of maize. However, increase the nitrogen rates it increase plant height. These findings are consistent with the results reported by Debele *et al.* (1994), who found that nitrogen application significantly increased the number of leaves per plant, plant height, and leaf length in maize.

Leaf length (cm)

Nitrogen application had non-significant effect ($p > 0.05$) on leaf length, as shown in Table 7.

Table.7 Mean of leaf length as influenced by Nitrogen level.

	Nitrogen Level				
Parameter	0kg/ha	60kg/ha	175kg/ha	250kg/ha	mean
LL	67.10a	76.63a	83.73a	68.73a	74.05
LSD (0.05)= 18.22					
CV (%)= 3.21					

In general application of different rates of nitrogen fertilizer was non-significant difference on leaf length. Increasing nitrogen fertilizer rates were increased leaf length on maize plant. The highest mean leaf length (83.73 cm) was recorded at the nitrogen application rates of 175 kg/ha, as presented in Table 6. Leaf length was reduced at both suboptimal and excessive nitrogen levels, indicating that insufficient or excessive nitrogen negatively impacts vegetative growth. The lowest leaf length was observed in the control treatment (0 kg/ha), which is attributable to nitrogen deficiency. Conversely, the treatment receiving 175 kg/ha nitrogen resulted in the maximum leaf length, demonstrating that optimal nitrogen application enhances leaf development. However, leaf length declined in the treatment with 200 kg/ha nitrogen, suggesting that excessive nitrogen application can adversely affect leaf elongation, possibly due to nutrient imbalances or toxicity. These results are consistent with the findings of Debele *et al*. (1994), who reported that nitrogen levels significantly influence leaf number and leaf length in maize.

CONCLUSION

This study demonstrated that nitrogen application significantly influences on key vegetative growth parameters of maize; plant height, leaf length, leaf area per plant, and the number of leaves per plant ($p < 0.05$) application of 175 kg N /ha consistently produced the highest values for plant height (69.4 cm), leaf length (83.73 cm), leaf area (871.42 cm²), and number of leaves per plant (10.03), indicating it as the optimal nitrogen rate for promoting vigorous vegetative growth. Nitrogen rates below or above 175 kg/ha resulted in reduced growth performance, likely due to nutrient deficiency or toxicity effects, respectively. Therefore, it is recommended that maize producers adopt an application rate of 175 kg/ha nitrogen to enhance vegetative growth and potentially maximize yield. Further research is warranted to refine nitrogen management practices under different locations and growing conditions.

Data Availability

The corresponding author can provide the datasets used to support the study's conclusions upon request.

Conflict of Interest

The writers affirm that they have no competing interests.

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