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Maize Growth and Yield Response to Incremental Rates of Nitrogen in N-Depleted Lixisols in Northern Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. Authors EAA and JXK planned the experiment and lead the research. Author EAA designed and carried out the research. Author EAA collected the data and performed the statistical analysis. Authors EAA, JXK and AMR wrote the manuscript. Author EAA managed the literature searches. All authors provided critical feedback and helped shape the research, analysis and manuscript. All authors read and approved the final manuscript.

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ABSTRACT

To help economize fertilizer use and predict soil-based and site-specific fertilization regimes in crop production, knowledge on crop response to incremental rates of nutrition have long been identified to play a significant role. In the nutrient-poor lixisols of northern Ghana where bulk of Ghanaian maize is produced, the response of maize growth and yield to eleven rates of N fertilization was evaluated in 2019 as a first step in developing a tool that could predict site-specific nitrogen rates for optimum maize production. The rates were 00, 15, 30, 45, 60, 75, 90, 105, 120, 135, and 150 kg/ha; laid out in a Randomized Complete Block Design. Collected maize growth and yield data were subjected to analyses of variance, where significantly different means were separated at a probability of 5% using the least significant difference. The study revealed no significant differences in plant height from the third to sixth week after planting, days to 50% flowering, 100 grain weight, and leaf area index at sixth week after planting. However, plant height and leaf area index at ninth week, cob weight, cob length, straw weight and grain yield were significantly affected by N fertilizer

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rates. Increasing nitrogen fertilizer rates had a pronounced effect on later-stages of growth, on grain yield and on yield components of maize. Application of 120 to 150 kg/ha N achieved statistically similar, and maximum growth and yield parameters compared to lower rates. The findings provide essential agronomic data required to relate soil test results with corresponding maize yield.

Keywords: Maize growth; grain yield and yield component; nitrogen fertilization; crop nutrition.

1. INTRODUCTION

Maize (*Zea mays* L.) is an incredibly versatile crop. A cereal crop that is widely cultivated worldwide in a large variety of agro-ecological environments [1,2]. In Ghana, it is the main staple food for most households, particularly in the northern part, where it has replaced sorghum (*Sorghum bicolor* L. Moench) and millet (*Panicum miliaceum* L. Garten) that were the staples some few years ago [3]. It is one of the most significant crops for Ghana's agricultural sector and for food security. Across the country, it is the principal source of carbohydrate for feeds in the poultry industry and for domestic livestock [4]. It is grown in all areas of Ghana including: the forest, transition, coastal savannah, and the northern savannah agro-ecological zones. It is grown on an estimated 1,000,000 hectares of land, contributing 50-60% of the total cereal production of Ghana and is thus one of the most significant crops for Ghana's agricultural sector and for food security [5]. The average maize yield in Ghana as at 2013 was 1.7 Mt/ha compared to an expected yield of around 6 Mt/ha [6,7]. With changing agricultural trends and a growing human population, the probability of continuous maize cultivation is widely being accepted. Farmers are increasingly dedicating more acres of farmlands to intensive crop sequences in which maize follows maize more frequently [8].

Nitrogen is a crucial plant nutrient and a noteworthy yield determining component for maize production [9,10]. The most important element required for the growth and development of plants is nitrogen. Crop growth rate slows down at low nitrogen availability, causing reduced development of reproductive structures and resulting in lower physiological development, growth and yield [10]. Its accessibility in adequate amounts all through the growing season is essential for optimum growth of maize. Most farmers in developing countries like Ghana, however, usually rely on natural soil fertility for crop production. The inherently low nutrient status of most of the soils, however, render them unsuitable for crop production [11], necessitating the addition of external nutrients to meet the crop's nutrient demand [12]. Where nutrient applications are done, successive fertilization with sole N have been noted to improve crop performance substantially. For instance, application of a mixture of urea, triple superphosphate (TSP) fertilizer and farmyard manure excrement was found to improve the crop use of N and P_2O_5 fertilizer [13]. Thereafter, subsequent cropping with sole nitrogen performed comparably to compound mixtures of fertilizers. Many studies, such as [9] reported that starter nitrogen has the ability to improve early development and yield. Nitrogen thus remains the most important nutrient that is required for maize growth in most nutrient-poor soils of Africa [14].

While efforts are made to have a comprehensive knowledge on the relative performance of all plant nutrients [15], it has been proposed that such efforts be garnered towards provision of comprehensive crop and soil data as well as products that would ensure tailor made, site specific nutrient formulation. Development of such site-specific nutrient prediction tools would require three tier levels of knowledge and data collection: Crop response to known soil fertility status as base for tool development, development and evaluation of the performance of the given predicting tool, and then validation of performance of the developed tool [16].

Across the largely lixisols of northern Ghana where maize is cultivated, limited data exists on crop responses to known soil nitrogen levels to serve as the first step in the development of nitrogen-predicting tools for maize production. This lack has hindered efforts that have aimed at developing site-specific fertilization regimes and has largely informed a one-suite recommended rate of 120 kg/ha of nitrogen for all sites irrespective of inherent differences and variations in nutrients at different locations. Therefore, this study was carried out to assess the response of maize growth, yield and yield components to known levels of soil nitrogen to serve as a knowledge base for the development of a nitrogen predicting-tool for site-specific nitrogen fertilization based on inherent soil nutrition.

2. MATERIALS AND METHODS

2.1 Experimental Site

The research was done in a pot (27 cm of height and 21 cm of diameter) in a glasshouse located at Nyankpala in the Guinea Savannah zone of northern Ghana. The greenhouse is located at a geographical positioning system latitude of 09°24'44.4" N and longitude 00°58'49.7" W. The area experiences a unimodal rainfall with an annual mean rainfall of 1000 to 1022 mm.

The temperature distribution is fairly uniform with a mean monthly minimum of 21.9°C and a maximum of 34.1°C. The area has a minimum relative humidity of 46% and a maximum of 76.8%. The soil for the study is a typical upland soil, developed from ironstone gravel and ferruginized ironstone [17]. The nature of the soil in the area is brown, moderately drained, sandy loam, free from concretions, developed from Voltaian sandstone and classified as flaplic lixisol which is locally referred to as the Nyankpala series [18]. The pot experiment was conducted from April to July 2019.

2.2 Experimental Design and Treatment

The study was a single factor experiment consisting of only inorganic nitrogen fertilization rate. Eleven levels of N were used as treatments. These were 00, 15, 30, 45, 60, 75, 90, 105, 120, 135, and 150 kg/ha N (Table 1). The experiment was laid out in a Randomized Complete Block Design to reduce errors associated with heterogeneity of conditions in the glasshouse. This was done to reduce experimental errors by eliminating the contribution of known sources of variations in the experiment. The experiment was replicated four (4) times for each treatment. There were forty-four (44) experimental pots in totality.

The estimated root zone certainty between rhizoshpere applied rate and rate due to continuous mass of soil (Table 1) was done by multiplying the actual rate by a factor of three. The factor of three represents an estimate of ratio of root zone surface area to total surface area between any two stands. This estimated root zone certainty was essential because, in the normal farmers' fields, any rate to be added per unit area are point applied within the root's rhizosphere and not randomly spread over the entire surface area. So that at any time, soils picked within the inter and intra rows would normally have lower nutrient concentrations than soils that would have been picked at the point where the fertilizers were applied. To ensure uniform concentration of nutrients at any sampled points of soils for the pot experiment, this proxy of nutrient estimate was essential. The estimated final rate of nutrient applied (Table 1) was then mixed thoroughly with 10 kg soil to have a uniform nutrient concentration within the potted soil, prior to planting. In this case when soil samples are taken for analysis, the nutrient concentration will not differ from one point to another.

Table 1. Rates of nitrogen used to study the response of maize growth and yield. ** N rates applied to the pot experiment to calibrate soil test results for nitrogen fertilization

Treatment	N calibration rate (kg/ha)	**N rate applied in pot experiment (kg/ha)	Mass of N (g/kg)	**Mass of N used (g N/ kg soil)
1	0	0	0.000	0.000
2	15	45	0.173	0.519
3	30	90	0.346	1.038
4	45	135	0.519	1.557
5	60	180	0.692	2.076
6	75	225	0.865	2.595
7	90	270	1.038	3.114
8	105	315	1.211	3.633
9	120	360	1.384	4.152
10	135	405	1.557	4.671
11	150	450	1.730	5.190

*** Estimated root zone certainty between rhizosphere-applied rate and rate due to continues mass of soil = three times the actual rate needed.*

2.3 Soil Sampling

Soil samples were collected from the experimental site at depth of 0-20 cm. The samples were transferred to the laboratory for analysis prior to cultivation. The collected samples were air-dried and passed through 2 mm sieve to remove large particles, debris and stones that were larger than 2 mm. Soil pH was determined by using the electrometric method in a soil: water ratio of 1:2.5. Organic carbon was determined by Wakley and Black procedure [19]. Total nitrogen was determined by the micro Kjeldahl method [20], while Bray 1 extraction solution procedure [21] was used for determination of available P. Textural analysis was by the hydrometer method. The soil was loamy sand in texture. The soil had a pH of 5.85 which is moderately acidic. The soil's available P was low and the exchangeable cations (K, Ca and Mg) were not also high. The total nitrogen and percentage organic carbon were also low.

2.4 Agronomic Practices

Hand-watering of the potted plants was done twice daily, in the morning and late afternoon, to enhance soil moisture and facilitate germination, and growth of the maize plants. Three (3) maize seeds were planted at stake. The maize plants were thinned-out, two weeks after planting to one plant per pot and all weeds that appeared in the pots were removed immediately by hand to prevent competition with the maize plants.

Phosphorus and potassium as P_2O_5 and K_2O respectively were applied as side placements at 10 days after emergence at respective rates of 60 kg/ha each. Urea was used as the source of N. Muriate of potash (KCl) was used as the source of K_2O (60%), while triple super phosphate (TSP) $Ca(H_2PO_4)$ was used as source of the P_2O_5 (45%).

2.5 Data Collection

Data were collected on the following: initial nutrient levels before fertilization, plant height, leaf area index, days to 50% flowering, straw weight, cob weight, cob length, cob weight, 100 seed weight, and grain yield.

2.5.1 Plant height

The height of the maize plants in each pot was measured at 3, 6 and 9 weeks after planting (WAP). Tape measure was used to measure the heights from the base of the plant to the flag leaf and their averages recorded [17].

2.5.2 Leaf area index (LAI)

Leaf area index was taken at 6 and 9 weeks after planting by measuring the length and the width of the leaves. LAI was computed by formula, L × W × A where L = leaf length, W = leaf width and A = is a factor of 0.75 for maize crop as described by Fang et al. [26].

2.5.3 Days to fifty per cent flowering

The number of days to 50% tasseling was determined as the number of days between when the crop was planted and when 50% of the plants have tasseled [17]. This was recorded when either of the two plants have tasseled on each pot.

Table 2. Initial soil physico chemical properties (0-20 cm). Values are means ± standard error of means

Parameters	Mean values	Methods
Bulk density (g/cm^3)	1.40 ± 0.254	Core method [22]
pH (1 : 2.5:: Soil : Water)	5.85 ± 0.29	Electrometric pH meter [23]
Organic carbon %	1.055 ± 0.041	Wakley and Black procedure[19]
Total Nitrogen (mg/kg)	0.101 ± 0.008	Micro Kjeldahl method [20]
Available Phosphorus (mg/kg)	7.457 ± 0.403	Bray 1 extraction solution procedure [21]
Exchangeable potassium (mg/kg)	65.0 ± 2.7	(NH_4OAc of pH 7) procedure [24].
Exchangeable calcium (Cmol+/kg)	1.8 ± 0.2	(NH_4OAc of pH 7) procedure [24]
Exchangeable magnesium (Cmol+/kg)	0.72 ± 0.09	(NH_4OAc of pH 7) procedure [24]
SAND %	77.44 ± 3.39	Hydrometer method [25]
SILT %	21.4 ± 0.985	Hydrometer method [25]
CLAY %	1.16 ± 0.07	Hydrometer method [25]

**Moisture content on air dry weight basis*

2.5.4 Cob length

The cobs from each treatment were selected and their length measured and their averages were recorded. A pair of calipers and a rule was used to measure the cob length [27].

2.5.5 Cob weight

The cobs were selected from each treatment and weighed and their averages recorded. An electronic scale was used to determine the cob weight at harvest [27].

2.5.6 Weight of hundred seeds

100 maize seeds in each pot were counted and weighed using an electronic scale [28].

2.5.7 Straw weight

The straws of harvested pots were weighed after harvesting and recorded. The harvested straw weights were converted into tons/ha (t/ha) using the equation used by Goswami [29] below.

$$\text{Straw weight (t/ha)} = \frac{\text{Straw weight (kg/pot) x Plant density}}{1000} \quad (1)$$

Where plant population density = number of plant stands in 10,000 m^2 when planted at spacing of 80 cm x 25 cm (interspacing arrangement for the pot experiment), at one seed per stand.

2.5.8 Grain yield

The grains obtained from pots were threshed, cleaned, dried and weighed in gram for each pot. Total weight of all the grains of a particular pot gives the grain yield in gram per pot and finally converted into tons/hectare (t/ha), using the equation 2 below, used by Goswami [29].

$$\text{Grain yield (t/ha)} = \frac{\text{Grain yield per pot } (\frac{\text{kg}}{\text{pot}}) \text{ x Plant density}}{1000} \quad (2)$$

Where plant population density = number of plant stands in 10,000 m^2 when planted at spacing of 80 cm x 25 cm (interspacing arrangement for the pot experiment), at one seed per stand.

2.6 Data Analyses

Data collected from the pot experiments were subjected to analysis of variance (Anova) to compare crop growth and yield responses between the treatment levels using Gensatat 18th edition. Treatment means were separated at a 5% probability level using the least significant difference.

3. RESULTS

3.1 Plant Height

The application of different rates of nitrogen did not have a significant effect (*P = .28*) on plant height at third week after planting. However, calibration rate of 120 kg N/ha recorded the longest height whilst 135 kg N/ha recorded the least height (Fig. 1). The application of different rates of nitrogen did not have a significant effect (*P = .31*) on plant height at the sixth week after planting. Generally, however, 105 kg N/ha recorded the highest height followed by 120 kg N/ha while 00 kg N/ha recorded the least height. Plant height at ninth week after planting was significantly affected (*P = .001*) by the application of different rates of N. 90 kg N/ha gave the highest height followed by 120 kg N/ha and 30 kg N/ha while 00 kg N/ha recorded the least height at ninth week after planting.

3.2 Leaf Area Index

The application of different rates of nitrogen did not have a significant effect (*P = .16*) on leaf area index at six (6) weeks after planting. There was a general increase in leaf area index at the sixth week after planting with increasing rates of N application. However, 135 kg N/ha recorded the highest leaf area index followed by 120 kg N/ha. Treatment 00 kg N/ha recorded the least leaf area index (Fig. 2). There was a significant difference (*P = .01*) between the different rates of nitrogen applied with respect to leaf area index at ninth week after planting. Treatment 150 kg N/ha recorded the highest leaf area index followed by 105 kg N/ha and 120 kg N/ha while 00 kg N/ha recorded the least leaf area index at ninth week after planting (Fig. 3).

3.3 Days to 50% Flowering

The application of different rates of nitrogen did not influence (*P = .17*) days to fifty per cent flowering. However, 120 kg N/ha, generally, recorded the least days to flower followed by 105 kg N/ha while 00 kg N/ha recorded the longest days to flower (Fig. 4).

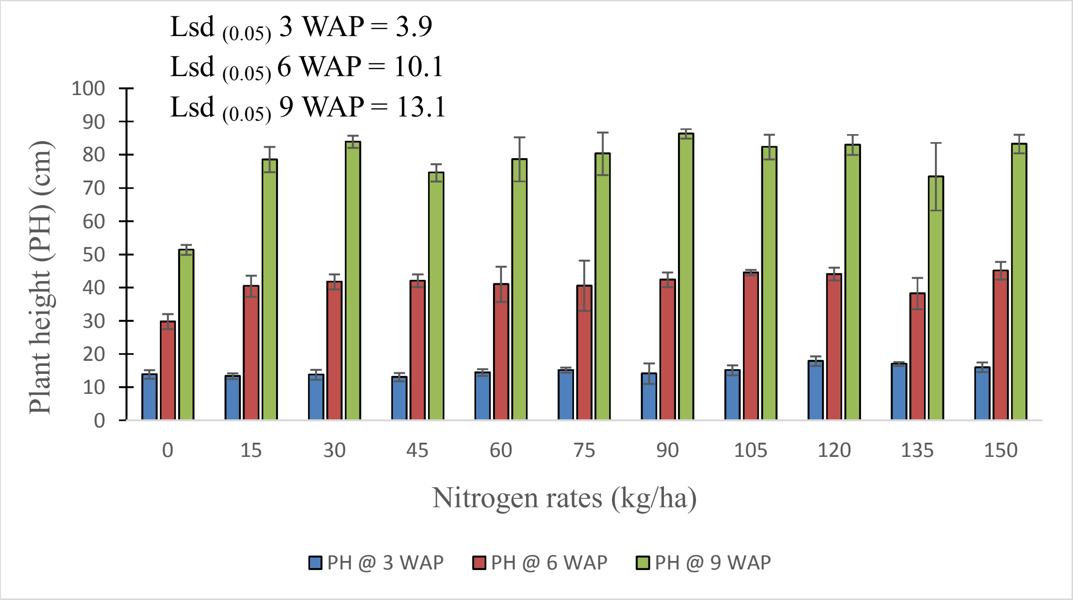

Fig. 1. Impact of nitrogen calibration rate on plant height of maize in the guinea savannah zone of Ghana

Bars are means, error bars represent standard error of means (SEM). Lsd represents Least significant difference at 5% probability. WAP = weeks after planting

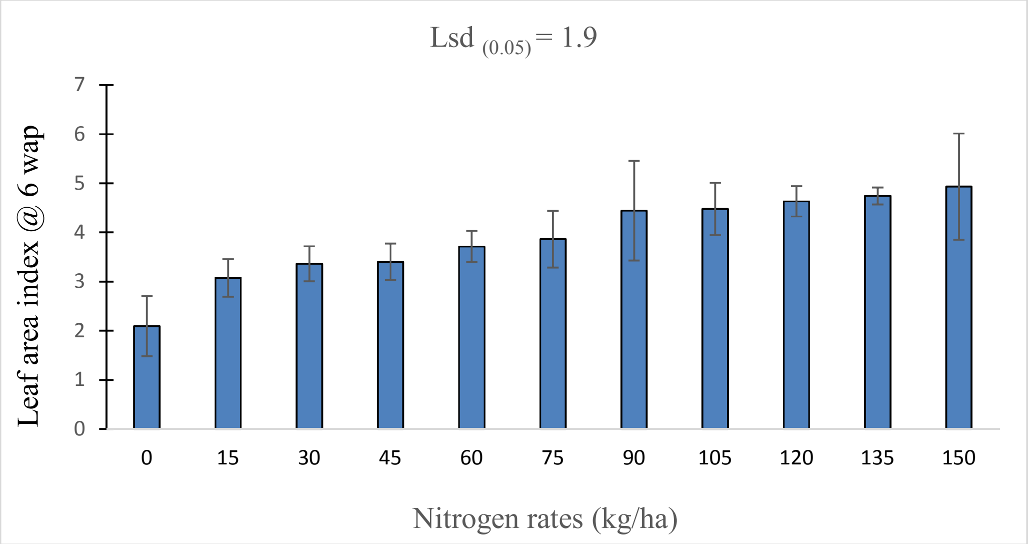

Fig. 2. Impact of nitrogen calibration rate on leaf area index of maize at six (6) weeks after planting (wap) in the guinea savannah zone of Ghana

Bars are means, error bars represent standard error of means (SEM). Lsd represents least significant difference at 5% probability. WAP = weeks after planting

3.4 Cob Weight

The application of different rates of nitrogen had a significant effect (*P* = *.03*) on cob weight. Application at rate of 90 kg N/ha recorded the highest weight of 27.13 g/cob followed by 105 and 135 kg N/ha with 26.06 g/cob and 26.0 g/cob respectively. Application of N at rate of 00 kg N/ha recorded the least weight of 17.6 g/cob (Fig. 5).

3.5 Cob Length

Nitrogen rate significantly (*P* = *.04*) influenced cob length. There was a general increase in cob length with increasing rates of N application (Fig. 6). Application of N at rate of 150 kg N/ha recorded the highest cob length of 15.3 cm followed by N application at rate of 120 kg N/ha and 135 kg N/ha, with 13.6 and 13.5 cm respectively; which were not significantly different. Application of N at rate of 00 kg N/ha recorded least cob length of 7.1 cm.

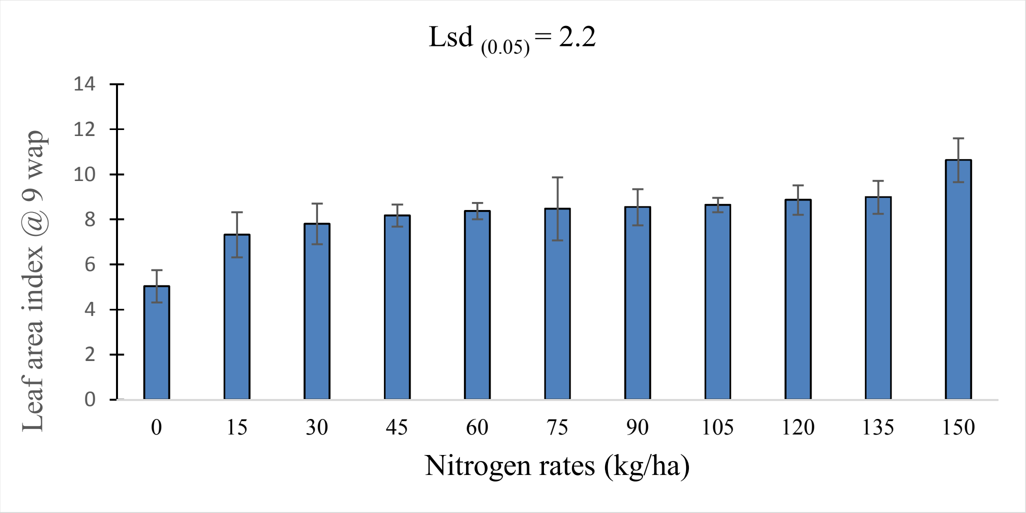

Fig. 3. Impact of nitrogen calibration rate on leaf area index of maize at nine (9) weeks after planting (wap) in the guinea savannah zone of Ghana.

Bars are means, error bars represent standard error of means (SEM). Lsd represents least significant difference at 5% probability. WAP = weeks after planting.

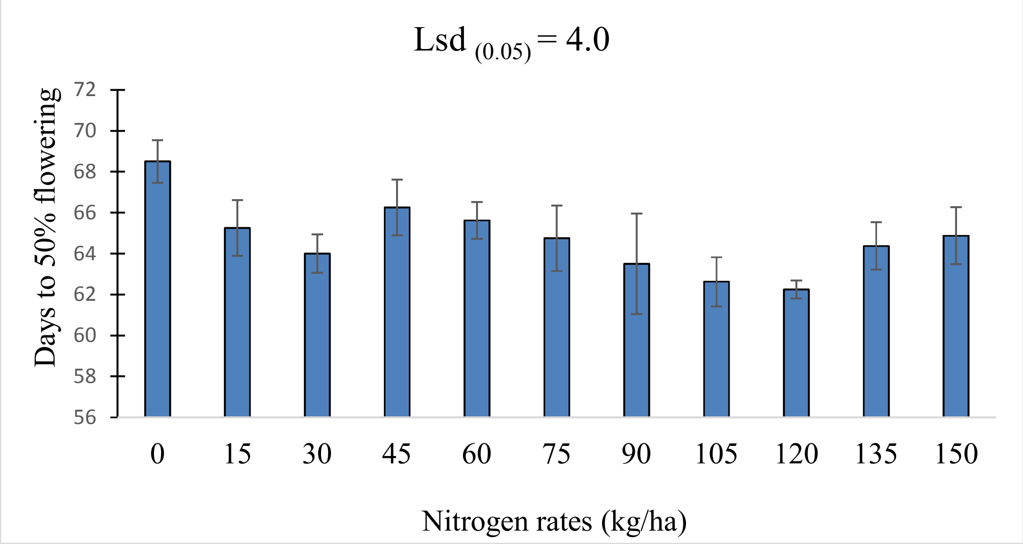

Fig. 4. Impact of nitrogen calibration rate on days to 50% flowering of maize cultivated in the guinea savannah zone of Ghana

Bars are means, error bars represent standard error of means (SEM). Lsd represents least significant difference at 5% probability. WAP = weeks after planting

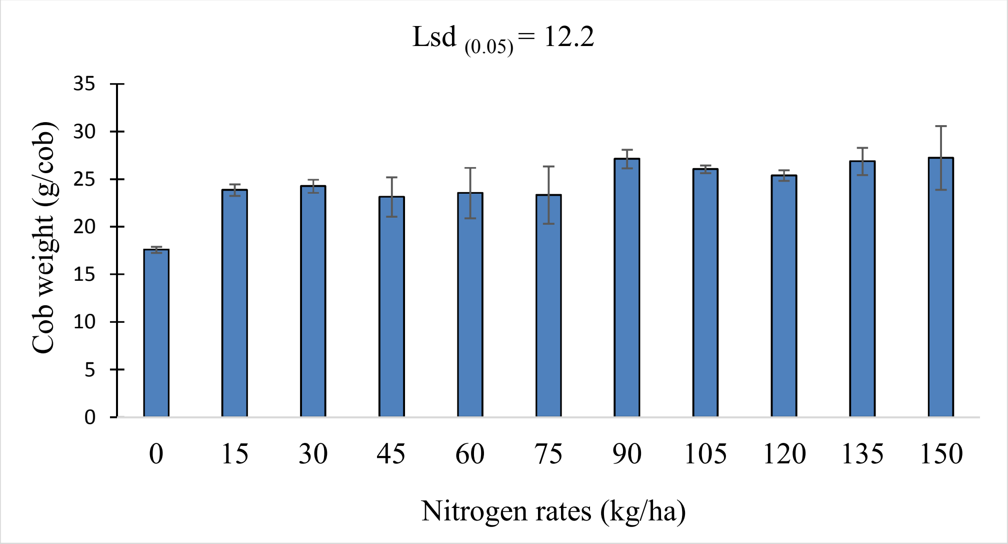

Fig. 5. Impact of nitrogen calibration rate on cob weight of maize cultivated in the guinea savannah zone of Ghana

Bars are means, error bars represent standard error of means (SEM). Lsd represents least significant difference at 5% probability. WAP = weeks after planting.

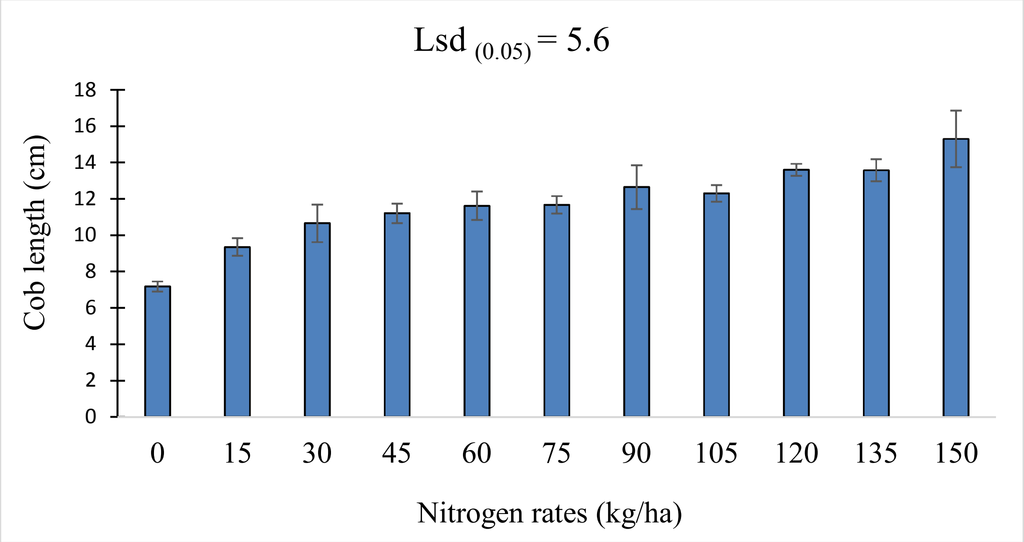

Fig. 6. Impact of nitrogen calibration rate on cob length (cm) of maize cultivated in the guinea savannah zone of Ghana

Bars are means, error bars represent standard error of means (SEM). Lsd represents least significant difference at 5% probability. WAP = weeks after planting.

3.6 Weight of 100 Seeds

The application of different rates of nitrogen did not have significant (*P* = *.15*) effect on hundred seed weight (Fig. 7). However, 75 kg N/ha, generally, recorded the highest hundred seed weight followed by 150 kg N/ha. Application at a rate of 00 kg N/ha generally recorded the least hundred seed weight.

3.7 Straw Weight

Nitrogen rate significantly (*P* = *.03*) influenced straw weight. Nitrogen application at rate

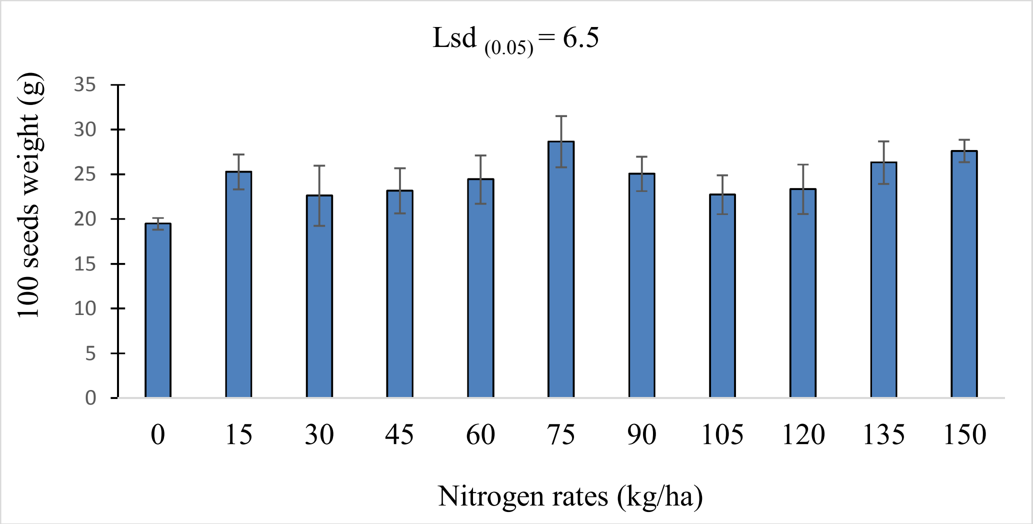

Fig. 7. Impact of nitrogen calibration rate on weight of 100 seeds of maize cultivated in the guinea savannah zone of Ghana

Bars are means, error bars represent standard error of means (SEM). Lsd represents least significant difference at 5% probability. WAP = weeks after planting

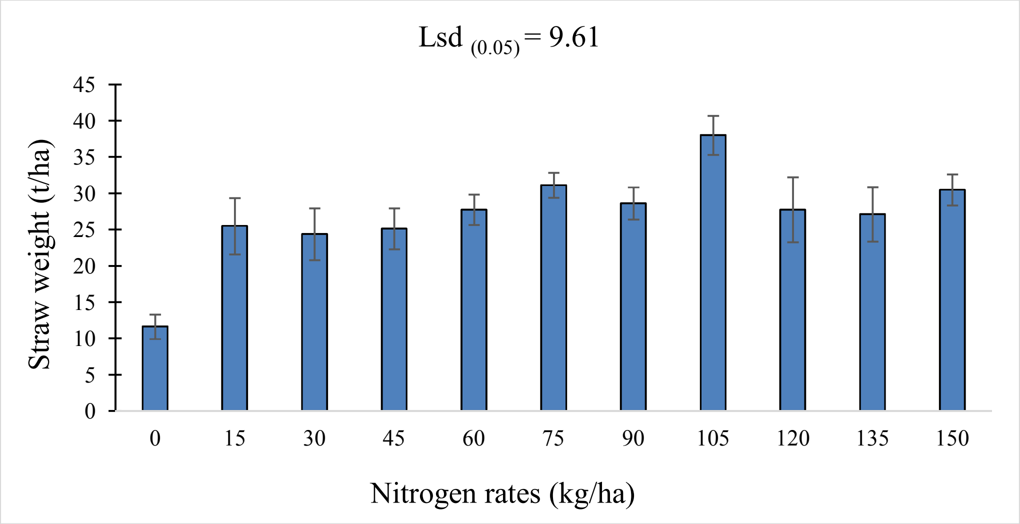

Fig. 8. Impact of nitrogen calibration rate on straw weight of maize cultivated in the guinea savannah zone of Ghana

Bars are means, error bars represent standard error of means (SEM). Lsd represents least significant difference at 5% probability. WAP = weeks after planting.

of 105 kg N/ha recorded the highest straw weight, followed by 75 and 150 kg/ha while 00 kg N/ha recorded the least straw weight (Fig. 8). Nitrogen application at a rate of 00 kg N/ha gave the lowest straw weight.

3.8 Grain Yield

Grain yield was significantly affected by rates of nitrogen (*P = 0.04*). There was a general increase in grain yield with an increasing rate of N application (Fig. 9). Nitrogen application at a rate of 150 kg N/ha recorded the highest yield of 4.65 t/ha followed by nitrogen application at rates of 135 kg N/ha and 120 kg N/ha which gave yields of 4.53 and 4.23 t/ha respectively. Application of nitrogen at a rate of 00 kg N/ha recorded the least grain yield of 1.08 t/ha.

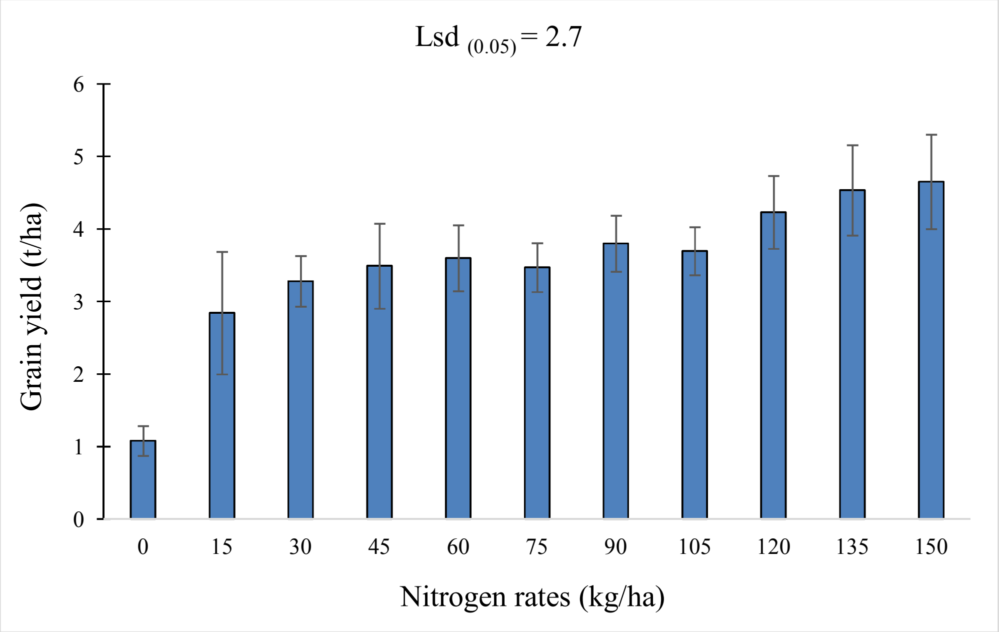

Fig. 9. Impact of nitrogen calibration rate on grain yield of maize cultivated in the guinea savannah zone of Ghana

Bars are means, error bars represent standard error of means (SEM). Lsd represents least significant difference at 5% probability. WAP = weeks after planting.

4. DISCUSSION

Fertilization, when it meets the plant nutrient requirement for growth and development results in optimum productivity. The insignificant difference in plant height at both third (3rd) and sixth (6th) week after planting (Fig. 1) could be due to similarities in nutrient environment across the various treatments at those stages of growth. The maize plant might have met its nutrient requirement across the treatments within the 3rd and 6th WAP. Similar results have been observed by Selassie [30], who reported that there was no significant variation between plant heights at early stages of growth. In contrast to the observation for the 3rd and 6th WAP, the observed variation in plant height at the ninth (9th) week after planting is attributed to differences in the N nutrient supplying ability of the various N rate treatments. Higher rates of N treatments may have had higher ability to supply the N nutrient as required for maize growth, resulting in vigorous vegetative growth and development of the maize plant and reflecting in the significantly taller plants at higher N rates by the 9th WAP. At latter and prime stages of development, plant tissues and organs are expected to be maturing at a higher pace, requiring much more N nutrients for morphological growth and physiological functions [31]. Therefore, treatments with lower N rate may not have met the quantity of N required for the enhancement of growth [32], resulting in the lower rate of growth observed in the low N rate treatments. Similar observations in plant height were observed by Matusso and Materusse [33] upon application of different rates of N fertilization. According to Arendt [34,35], such differences are attributed to the relative efficiency of nutrient uptake in the higher rates of N fertilization by the growing roots which makes plants compete favorably for growth factors and convert the available scarce nutrients and growth factors into physiological development. In a study by Bationo et al. [36], they also concluded that the amount of nutrient that is made available to maize plant is directly related to its growth, development and maturity which is in agreement with the reasoning alluded to in the finding of this study.

The observed significant effect (*P* = *.01*) of nitrogen fertilizer rates on leaf area index (Fig. 3) is in agreement with results by Abera et al. [37] who also noted highly significant variation in leaf area index as affected by the application of nitrogen fertilizer rates. The increase in leaf area index with increasing N fertilization rate is favorable for morphological and physiological development [38] as the relatively higher leaf surface area could increase the overall contact surface to capture light for photosynthesis [39]. The higher the rate of photosynthesis, the more energy there is for plant growth and development [40]. According to Abera et al. [37] such observed increases in leaf area index with increasing rates of nitrogen fertilizer application shows the important role of nitrogen in leaf development, sun interception and the associated growth and development of the maize crop.

The observed significant difference (*P = .02*) among the N application rates on cob weight, with 90 kg N/ha recording the highest cob weight of 27.13 g/cob while the zero control plot recorded the least cob weight of 17.6 g/cob is in agreement with findings of Majid et al. [41] who noted similarly low cob weight in treatments that received no nitrogen fertilization and highest cob weight under higher N rate treatments. The increases in cob weight with increasing N fertilization could be due to enhanced N nutrient availability at higher rates, which has an influence on the absorption and uptake of available nutrients [42]. Mvubu et al. [43] noted and observed that application of nitrogen at higher rates increased cob weight up to 61.6 g/cob, and reports by Costa et al. [44-46] show that cob weight increases with increasing rates of nitrogen application.

The differences observed among the N application rates on cob length, where application rate of 150 kg N/ha recorded the longest cob length 15.3 cm among all the treatments and 00 kg N/ha recorded the least cob length of 7.1 cm (Fig. 6) is in agreement with findings of Majid et al. [41]. The authors found similarly shorter cob length in treatments that received no nitrogen fertilization and longest cob length under higher N rate treatments. Ngosong et al. [47] in their study, showed that different N rates had significant variation on maize cob length in the range of 14.5 to 18 cm as compared to the control, while [10] also reported that application of nitrogen generally promotes growth and yield components of maize and results in longer cob length.

Maize straw weight was significantly affected by the application of different nitrogen rates. Highest straw weight was obtained by 105 kg N/ha at 38.0 t/ha and almost all the other treatments showed a similar performance as compared with the control plot. This result shows a high response of straw weight to nitrogenous fertilizers, irrespective of the rate. 00 kg N/ha recorded the minimum straw weight of 11.62 t/ha. According to reports by Rurangwa et al. [48], successive increment of nitrogen rate from 0 to 120 kg/ha remarkably increased dry weight of maize plant. The distinction in the dry matter accumulation in maize at higher rates is ascribed to post silking N uptake which improves with increments in nitrogen application rate [31, 49].

The observed significant (*P = .04*) influence of N application rate on grain yield, where grain yield increased with increasing N application rate (Fig. 9) with maximum yield of 4.65 t/ha at 150 kg N/ha followed by 135 and 120 kg N/ha with yields of 4.53 and 4.23 t/ha respectively; while minimum yield of 1.08 t/ha was obtained by 00 kg/ha, implies that increasing nitrogen fertilization in nutrient-poor soils optimizes maize growth and yield in the nitrogen-poor soils. This observation is in line with findings of numerous researchers. Olarinde [8, 50, 51] ascribed such increases in maize grain yield to the overall enhancement in soil chemical, and biological properties as relates to ample fertilizer application. The growth, development, maturity and yield of the crop are directly related to the amount of nutrients that is made available to the crop during its growth period without wastage to the environment [36, 52,53]. The enhancement in soil nutrient content with increasing N rate may have favoured the chemical composition of the soil for better nutrient utilization [40]. As observed in the case of plant height (Fig. 1), leaf area (Fig. 3) and other growth and yield attributes (Fig. 2 to Fig. 9), high N rates tendered to favour maize growth parameters and result in better physiological and morphological performance, light interception and photosynthesis which in turn reflected in the higher grain filling abilities and yield of the maize plant [54, 55].

The results on maize response to N fertilization serve as the first entry point in a three-tire levels of study for development of comprehensive crop and soil data as well as an N-predicting tool that could help to estimate tailor made, site-specific nutrient formulation. The next step is to develop the tool that can predict soil fertility status and the required nitrogen top-up that is needed for optimum maize production, followed by evaluation and validation of the developed tool. The developed tool will aid scientists and researchers to predict site-specific fertilization that are based solely on maize nutrient requirement and the results of soil laboratory analyses. This will eliminate the current approach of using a one-suite recommended rate of 120 kg/ha of nitrogen for all sites irrespective of the inherent differences and variations in soil nutrients at different locations.

5. CONCLUSION

In the nitrogen-depleted lixisols of northern Ghana, increasing nitrogen fertilizer rates by a factor of 15, from 00 to 150 kg/ha, had pronounce effect on growth, grain yield and yield components of maize. Nitrogen application at 150 kg/ha achieved the maximum yield and yield parameters, but in most cases it was statistically similar with N rates of 135 and 120 kg/ha, indicating that a rate of 120 kg/ha is suitable for the N-depleted lixisols of northern Ghana. Application of nitrogen fertilizer at the optimum rate increased growth and grain yield in maize production and provides the much needed data on crop response to known N-levels as a base requirement for developing site-specific fertilization regimes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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