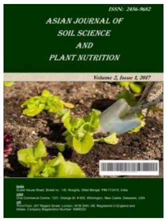

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Prediction of Nitrogen Application in Maize Based on the Normalised Difference Vegetation Index (NDVI)

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Authors' contributions

This work was carried out in collaboration between all authors. Author LBA designed the study and wrote the protocol, author RIA performed the statistical analysis, wrote the first draft of the manuscript and managed the analyses. Author OEG managed the field activities, data recording and while author AMO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine the quantity of nitrogen required for vegetative, yield and yield components of maize and to predict these attributes using the normalised difference vegetative index.
Study Design: Experiment was carried out in randomized complete block design five treatments and replicated three replicates.
Place and Duration of Study: Field experiment was carried out at Ladoke Akintola University of Technology at Teaching and Research Farm, Ogbomoso (latitude 8º10' N, longitude 04º10' E and elevation 1,286 m), Nigeria, during the raining season between June and October of 2015.
Methodology: Seeds of nine maize hybrids were obtained from the International Institute of Tropical Agriculture, Ibadan, and submitted to five nitrogen rates (0, 80, 100, 120 and 140 kg Nha^{-1}). Seeds were sown in two 5 m row plots with 0.75 m space between rows and 0.5 m within rows. Data of NDVI at 2, 3 and 4 weeks after planting (WAP), number of leaves, plant height, cob

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weight, grain weight, harvest index of cob and grain were collected and subjected to analysis of variance (ANOVA).

Results: The ANOVA indicated significant variation ($P \leq 0.05$) among nitrogen treatments for all growth and yield parameters. There was a significant correlation between NDVI values and grain yield per hectare indicating that NDVI can be used to predict maize performance. As a result of the magnitude of the correlation coefficient between NDVI at 4 WAP and grain yield (GY), regression analysis was computed between these two parameters; for every possible change in the value of NDVI 4 WAP, the corresponding equation: GY = 2592.5 + 9653.5 x (NDVI 4WAP).

Conclusion: The study concluded that application of 140 kg Nha^{-1} nitrogen fertiliser improves yield and yield components of maize. Moreover, judicious application of remote sensing (based on the NDVI) can be used to predict maize performance, thereby enhancing nutrient and other resource management in maize and ensuring high grain yield production.

Keywords: Maize; hybrids; NDVI; nitrogen.

1. INTRODUCTION

Maize (*Zea mays* L.) is a major staple food and a popular source of calories in Africa [1,2]. Maize has become a major cash crop for the resource-limited small-scale farmers in sub-Saharan Africa after successfully displacing the traditional African cereals like millet and sorghum through improved yield performance [3]. Maize has a diverse use that is not limited to the grain, but cuts across to the whole part of the plant whether fresh or dried; hence it has earned a place as an important industrial raw material.

As important as maize has become, its yield, however, fluctuates among the commonly cultivated varieties depending on the production zone, available soil nutrient as well as the applied cultural practices. Most West African soil are inherently low in plant nutrients especially nitrogen and phosphorus [4]. Nitrogen (N) is an essential plant nutrient and a major yield-determining nutrient for maize [5]. Furthermore, nitrogen influences plant biomass more than any other nutrient element as it is an indispensable component of many organic metabolites including amino acids, nucleic acids and phytochromes [6]. Hence, nitrogen is the driver of plant growth and it makes up about 4% of dry matter of plants [7].

Generally, crops grown on N-deficient soils exhibit distinctive N-deficiency symptom including poor growth, chlorosis and disordered physiological and biochemical attributes [8]. Most resource limited farmers of developing countries rely on the inherent soil fertility for crop production; opening up of fallow land may provide adequate nutrient for crops but utilisation of such land is only successful for a limited period. Thereafter, subsequent cropping requires additional fertiliser use.

The results of several nutrient requirement researches conducted in Nigeria have resulted to fertiliser recommendations that gave blanket requirements for maize in different ecologies [9]. This practice aims at giving farmers a fairly appreciable economic return from fertiliser use. Reports had highlighted that application of high amounts of urea is capable of causing nutrient imbalance and consequently yield depression in maize, hence there is a need to evaluate the effects of different nitrogen recommendations in Nigeria as available fertiliser recommendations were made long time ago and on open pollinated maize varieties and not hybrids that are commonly cultivated presently.

The uses of new remote-sensing tools that are based on irradiation to estimate green biomass standing on the field level are becoming increasingly important in maize hybrid testing and selection [10]. The GreenSeeker(R) handheld optical sensor unit [11] is a spectroradiometer that has been proposed for phenotyping in maize adaptation [12]; it is used to measure normalised difference vegetation index (NDVI). NDVI measurements uses a numerical indicator to analyse remote sensing measurements and has been described to be highly correlated with grain yield in maize and other crops [12,13]. NDVI is calculated with the measurements of reflectance taken in the visible region and near infrared region of the spectrum [9]. NDVI is a system of monitoring the vigour of the green vegetation growth or biomass was found to be equivalent to the leaf area of a plant and, thus, an efficient part of the photosynthetic process which eventually determines final grain yield [12,14]. Maize hybrids that amass ample biomass as shown by high NDVI values at the seedling stage of the crop would be likely to produce high grain yields at harvest. In order to assess the value of NDVI in a new hybrid maize breeding program, this study was conducted to examine the relationships between NDVI and nitrogen levels on a set of newly developed maize hybrids.

2. MATERIALS AND METHODS

2.1 Description of Study Location and Seed Material

Field experiment was conducted during the raining season of 2015 at the Ladoke Akintola University of Technology (LAUTECH) Teaching and Research Farm, Ogbomoso to study the influence of different nitrogen levels on the performance of maize. Ogbomoso is located at 08º10´ N and 04º10´ E, and elevation 1,286 m above sea level with average annual rainfall of 1,000 mm [15].

The study aimed to evaluate the influence of different nitrogen levels on the performance of maize. Nine maize hybrids obtained from the International Institute of Tropical Agriculture (IITA), eight of which were selected from an on-going drought tolerant maize trial (ADL 32 × ADL 35, ADL 32 × ADL 36, EXL 32 × ADL 39, EXL 06 × ADL 39, EXL 15 × EXL 04, EXL 01 × EXL 05, LY1001-22, LY1001-23) and one (Oba Super 2) which is a commercial hybrid as check.

2.2 Treatments and Experimental Design

The experiment was carried out in a factorial experiment with three replicates and nine maize hybrids were subjected to five nitrogen levels (0, 80, 100, 120 and 140 kg N ha^{-1}).

2.3 Crop Conduction and Management

The land was mechanically cleared and ridged at 0.75 m apart. Each row was 5 m long with 0.75 m between rows and 0.5 m within plants in a row. Three seeds were sown per hole and were later thinned to two plants per stand at two weeks after planting (WAP) to give 53,333 $plantsha^{-1}$. The nitrogen was applied as urea in two splits at 2 and 4 WAP while the recommended 60 kg P and K for maize in Nigeria was supplied. A mixture of gramoxone and primextra was applied as pre-emergence herbicides at 5.0 L ha^{-1} each of paraquat (N, N-dimethyl-4, 40-bipyridinuim dichloride) and atrazine (2-Chloro-4-ethylamino-6-isopropylamino-1, 3, 5-triazine). Subsequently, manual weeding was done to keep the trial weed-free.

2.4 Variables Evaluated

2.4.1 Growth and yield of the maize

Plant height and number of leaves at 4, 6, 8 and 10 WAP were collected in each plot. Other data taken included yield and yield component, as follows: cob weight (CW) was obtained by measuring the weight of the cobs harvested (kg ha^{-1}), grain yield (GY) obtained by shelling all ears harvested from each plot and a representative grain sample was taken to determine percent moisture. GY measured in kg ha^{-1} adjusted to 15% moisture content was calculated from grain weight and percent moisture. Harvest index of cob (HIC) and harvest index of grain (HIG) was calculated by dividing the cob and grain weight, respectively, by the total biomass weight.

2.4.2 Normalised difference vegetation index (NDVI) measurement

The GreenSeeker(R) handheld optical sensor unit [11], installed with red sensor, red waveband centred at 650 ± 10 nm, and near infra-red (NIR) band centred at 770 ± 15 nm, was used to collect NDVI measurements in each plot. The device was held at about 60 cm above the canopy while each plot was recorded, starting from the beginning of the row to the end. Readings were taken in each plot at 2, 3 and 4 WAP.

2.5 Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using the Procedures for General Linear Model (PROC GLM) in SAS [16]. Correlation coefficients between every pair of measured variables and yield per hectare was computed using PROC CORR in SAS. Regression of NDVI 4WAP values on GY was subsequently computed following the results of the correlation analysis using PROC REG in SAS [16].

3. RESULTS

3.1 Plants Height and Number of Leaves of Maize

The height of maize plants were significantly influenced ($P \leq 0.01$) by maize hybrids and N-levels at all weeks of measurement. In general, the interaction between the maize hybrids and the N-levels was not significant ($P > 0.05$) at all weeks of measurement (Table 1). At 4 WAP, application of 120 kg N ha^{-1} to LY1001-23 produced the tallest plant (26.78 cm) which was not significantly different from the height (26.67 cm) of 100 kg N ha^{-1}. The trend was similar at 5 and 6 WAP. However, at 10 WAP, LY1001-23 produced the tallest plant across each applied N level while ADL 32 x ADL 35 produced the least crop height across all N-levels.

The number of leaves of maize were significantly influenced ($P \leq 0.01$) by maize hybrids and N-levels. Except at 10 WAP, the interaction between the maize hybrids and the N-levels was not significant ($P > 0.05$) at all weeks of measurement (Table 2). Application of 120 kg N ha^{-1} to LY1001-23 and EXL 01 x EXL 05 produced the highest number of leaves at 4 WAP. The highest mean number of leaves (7.89) at 5 WAP produced by application of 120 kg N ha^{-1} to EXL 15 x EXL 04 was not significantly different from 7.67 produced by LY1001-23 at the same N-level. At 6 and 10 WAP, the check (Oba Super 2) treated with 140 kg N ha^{-1} produced the highest values which were not statistically different from the mean number of leaves obtained from LY1001-23 at the same application rate.

3.2 Yield of Maize

The evaluated yield parameters (cob weight - CW, grain yield - GY, harvest index of cob - HIC and harvest index of grain - HIG) were significantly influenced ($P \leq 0.01$) separately by hybrids and N-levels but no interaction was observed (Table 3). For CW, the highest values varied between 80 and 100 kg N ha^{-1} with these values being mostly not significantly different from each other. The overall highest CW value (648.67 kg ha^{-1}) occurred on EXL 01 × EXL 05 at 140 kg N ha^{-1} while the least (320.67 kg ha^{-1}) was obtained on unfertilised EXL 02 × ADL 39. Similarly, the highest HIG values was also recorded between 80 and 120 kg N ha^{-1}; the peak HIC value (51.93) was obtained from EXL 06 × ADL 39 at 80 kg N ha^{-1} while the least value (28.29) occurred on EXL 01 × EXL 05 that received no fertiliser though this was not significantly different from the values recorded from unfertilised LY1001-22 and LY1001-23. Furthermore, for GY, LY1001-23 produced the highest yield (8588.15 kg ha^{-1}) at 140 kg N ha^{-1}while the least value (4514.81 kg ha^{-1}) was produced by Oba Super 2 at 0 kg N ha^{-1}.

3.3 Normalised Difference Vegetation Index of Maize

N-levels and maize hybrids significantly influenced ($P \leq 0.01$) the NDVI values throughout the period of recording. The interaction between the maize hybrids and N-levels was not significant ($P > 0.05$) all through the observation period (Table 4). At 2 WAP, application of 80 kg N ha^{-1} consistently produced the highest NDVI values across the maize hybrids but the values were not significantly different from the values produced by application of 100 kg N ha^{-1} while plots that received no fertiliser steadily produced the least vegetative index across the hybrids. The highest NDVI value recorded at 2 WAP (0.31) was recorded on LY1001-22 at 80 kg N ha^{-1}. At 3 WAP, however, there was no consistency in the expression of the vegetative index, LY1001-23 had the highest vegetative index (0.46) under application of 120 kg N ha^{-1} while the least NDVI value (0.33) was obtained from EXL 01 x EXL 05. At 4 WAP, higher NDVI values that were not significantly different from one another were recorded. The highest NDVI value (0.56) was again recorded on LY1001-22 treated with 100 kg N ha^{-1} while the least (0.34) was recorded on EXL 06 × ADL 39 and EXL 01 × EXL 05 planted without application of N fertiliser.

3.4 Biomass

Table 5 presents the influence of N-levels and maize hybrid on the biomass accumulation of maize; both N-levels and maize hybrid significantly ($P \leq 0.01$) influenced total biomass of the evaluated hybrids. The highest biomass (31532.00 kg ha^{-1}) was produced by LY001-22 at 100 kg N ha^{-1} while the lowest was recorded from Oba Super 2 (13115.70 kg ha^{-1}) recorded from no fertiliser treatment.

3.5 Trait Correlation and Regression

Table 6 presents the Pearson correlation coefficients between the evaluated parameters and maize yield; the three NDVI records were significantly correlated with yield per hectare with NDVI at 4 WAP having the highest coefficient ($r = 0.48$; $P \leq 0.01$) with grain yield per hectare. The number of leaves at 5, 6 and 10 WAP were negatively and not significantly correlated with yield while plant height was positively and significantly correlated to yield all through the period of study.

Table 1. Effects of N-levels on the height of maize hybrids

Hybrid	N LEVEL kg N/ha					Hybrid	N LEVEL kg N/ha				
	0	80	100	120	140		0	80	100	120	140
	Height (cm) 4 weeks after planting						Height (cm) 6 weeks after planting				
ADL 32 × ADL 35	17.67	17.89	21.66	22.33	18.20	ADL 32 × ADL 35	36.45	35.39	58.33	46.89	38.50
ADL 32 × ADL 36	17.33	18.55	22.00	21.33	17.26	ADL 32 × ADL 36	38.94	33.35	49.89	46.78	40.39
EXL 02 × ADL 39	17.56	17.56	23.55	20.00	18.95	EXL 32 × ADL 39	38.22	37.27	57.22	39.56	42.98
EXL 06 × ADL 39	18.44	19.45	21.89	21.00	19.59	EXL 06 × ADL 39	42.33	37.39	55.78	49.56	46.61
EXL 15 × EXL 04	16.78	15.00	17.00	16.89	15.60	EXL 15 × EXL 04	42.67	29.06	44.89	40.22	37.85
EXL 01 × EXL 05	15.44	15.56	19.89	17.11	15.68	EXL 01 × EXL 05	38.11	29.52	52.89	42.33	34.39
LY1001-22	18.45	20.00	24.33	19.89	20.88	LY1001-22	42.22	39.73	55.78	46.33	41.50
LY1001-23	21.33	21.00	24.67	26.78	23.95	LY1001-23	49.33	37.32	55.56	63.34	51.28
Oba Super 2	17.89	17.78	26.44	22.33	20.69	Oba Super 2	41.78	29.02	61.00	45.55	43.83
		P > F						P > F			
LSD N	1.37	0.0001				LSD N	3.63	0.0001			
LSD VAR	1.84	0.0001				LSD VAR	4.87	0.0001			
LSD N X V	ns	0.82				LSD N X V	Ns	0.46			
	Height (cm) 5 weeks after planting						Height (cm) 10 weeks after planting				
ADL 32 × ADL 35	26.55	25.77	39.00	33.78	31.18	ADL 32 × ADL 35	131.44	130.44	143.50	144.89	135.22
ADL 32 × ADL 36	25.89	27.31	36.11	34.45	27.24	ADL 32 × ADL 36	136.11	135.11	151.89	143.33	140.95
EXL 02 × ADL 39	28.11	28.01	39.45	30.33	30.56	EXL 02 × ADL 39	158.67	154.56	175.39	164.22	159.78
EXL 06 × ADL 39	30.56	26.23	40.78	30.56	30.87	EXL 06 × ADL 39	140.78	139.56	143.89	142.22	145.22
EXL 15 × EXL 04	28.56	22.57	30.33	27.78	26.37	EXL 15 × EXL 04	166.22	165.78	168.94	171.11	168.00
EXL 01 × EXL 05	26.44	23.53	39.56	28.78	23.28	EXL 01 × EXL 05	161.44	162.22	177.33	170.89	177.00
LY1001-22	31.00	29.95	41.22	29.44	33.39	LY1001-22	172.67	169.78	173.95	175.22	167.33
LY1001-23	33.78	29.33	42.33	47.11	36.55	LY1001-23	185.00	177.44	183.50	189.67	186.00
Oba Super 2	28.33	24.58	45.33	33.33	31.19	Oba Super 2	158.67	140.33	174.50	140.78	156.89
		P > F						P > F			
LSD N	2.36	0.0001				LSD N	5.12	0.0001			
LSD VAR	3.17	0.0001				LSD VAR	6.88	0.0001			
LSD N X V	Ns	0.11				LSD N X V	Ns	0.37			

Table 2. Effects of N-levels on the number of leaves of maize hybrids

Hybrid	N LEVEL kg N/ha					Hybrid	N LEVEL kg N/ha				
	0	80	100	120	140		0	80	100	120	140
	Number of leaves 4 weeks after planting						Number of leaves 6 weeks after planting				
ADL 32 × ADL 35	5.00	6.78	4.44	7.67	5.89	ADL 32 × ADL 35	7.11	9.78	9.55	8.67	9.11
ADL 32 × ADL 36	4.89	6.89	4.11	7.89	6.11	ADL 32 × ADL 36	7.33	9.33	8.55	8.11	9.00
EXL 02 × ADL 39	4.78	6.78	5.00	7.33	6.22	EXL 02 × ADL 39	6.22	7.56	8.22	7.89	8.67
EXL 06 × ADL 39	5.11	7.56	4.78	7.45	6.33	EXL 06 × ADL 39	6.78	8.89	8.11	8.00	8.89
EXL 15 × EXL 04	5.33	7.11	5.56	7.67	6.56	EXL 15 × EXL 04	6.67	9.00	7.11	8.11	8.89
EXL 01 × EXL 05	5.00	7.44	5.11	8.11	6.89	EXL 01 × EXL 05	6.89	8.78	8.11	8.67	8.45
LY1001-22	5.00	6.89	5.22	7.00	6.22	LY1001-22	7.33	7.78	8.67	8.33	8.55
LY1001-23	5.44	7.45	5.33	8.11	6.11	LY1001-23	7.67	7.89	8.44	8.67	9.00
Oba Super 2	4.55	6.56	4.55	7.22	6.22	Oba Super 2	7.56	7.89	10.11	8.22	9.00
		P > F						**P > F**			
LSD N	0.36	0.0001				LSD N	0.44	0.0001			
LSD VAR	0.48	0.01				LSD VAR	0.59	0.04			
LSD N X V	Ns	0.96				LSD N X V	ns	0.54			
	Number of leaves 5 weeks after planting						Number of leaves 10 weeks after planting				
ADL 32 × ADL 35	7.44	7.56	5.67	6.66	6.89	ADL 32 × ADL 35	11.00	12.22	12.34	12.44	12.89
ADL 32 × ADL 36	6.78	7.34	5.56	7.33	7.55	ADL 32 × ADL 36	11.22	11.22	11.78	12.44	13.11
EXL 02 × ADL 39	6.89	5.89	5.22	6.78	6.78	EXL 02 × ADL 39	12.00	8.56	12.11	12.00	13.67
EXL 06 × ADL 39	7.56	7.00	5.89	7.33	7.56	EXL 06 × ADL 39	12.22	8.89	12.00	11.78	13.00
EXL 15 × EXL 04	7.00	7.22	5.56	7.89	7.11	EXL 15 × EXL 04	11.56	10.00	12.00	12.56	13.33
EXL 01 × EXL 05	6.89	7.11	5.78	7.22	6.56	EXL 01 × EXL 05	11.89	10.44	12.56	12.11	13.67
LY1001-22	7.00	6.45	5.56	6.67	6.11	LY1001-22	12.67	10.00	11.78	12.00	13.11
LY1001-23	7.56	6.33	5.89	7.67	7.11	LY1001-23	12.33	11.11	11.89	12.11	13.78
Oba Super 2	6.78	5.89	5.78	7.67	7.33	Oba Super 2	13.44	12.11	12.00	12.45	14.00
		P > F						**P > F**			
LSD N	0.37	0.0001				LSD N	0.49	0.0001			
LSD VAR	Ns	0.09				LSD VAR	0.65	0.03			
LSD N X V	Ns	0.06				LSD N X V	0.32	0.03			

Table 3. Effects of N-levels on the yield parameters of maize hybrids

Hybrid	N LEVEL (kg/ha)					Hybrid	N LEVEL(kg/ha)				
	0	80	100	120	140		0	80	100	120	140
	Cob weight (kg/ha)						Harvest index of grain (HIG)				
ADL 32 × ADL 35	6894.23	8906.44	8207.75	8701.39	7637.76	ADL 32 × ADL 35	34.38	42.31	36.05	36.14	35.93
ADL 32 × ADL 36	6358.31	8649.71	9715.06	8847.36	7805.39	ADL 32 × ADL 36	34.85	38.1	37.64	38.08	34.41
EXL 02 × ADL 39	7388.86	9473.01	10213.54	7667.32	8269.6	EXL 02 × ADL 39	29.44	38.64	33.22	39.44	34.2
EXL 06 × ADL 39	7861.17	8238.16	9837.37	9482.66	8591.94	EXL 06 × ADL 39	37.12	42.87	33.68	40.86	32.09
EXL 15 × EXL 04	8188.59	9222.43	8593.48	8212.92	8212.5	EXL 15 × EXL 04	32.32	36.89	35.63	40.33	30.67
EXL 01 × EXL 05	6909.16	9948.48	9125.27	7370.47	7856.44	EXL 01 × EXL 05	28.29	41.93	30.15	35.36	36.16
LY1001-22	8103.65	10946.73	9944.42	8754.44	7650.86	LY1001-22	28.44	27.83	24.46	29.23	28.92
LY1001-23	10413.97	8296.18	10523.96	11129.95	10652.38	LY1001-23	28.43	30.49	31.44	28.36	32.22
Oba Super 2	5582.49	7649.8	7771.26	8767.51	7217.37	Oba Super 2	34.45	40.7	31.63	38.17	36.31
		P > F						P > F			
LSD N	865.36	0.0006				LSD N	2.7	0.0001			
LSD VAR	1161	0.0014				LSD VAR	3.62	0.0001			
LSD N X V	Ns	0.65				LSD N X V	ns	0.66			
	Grain yield (kg/ha)						Harvest index of cob (HIC)				
ADL 32 × ADL 35	5428.89	7250.37	7044.44	6777.78	5945.18	ADL 32 × ADL 35	43.48	51.86	42.14	46.43	46.47
ADL 32 × ADL 36	5027.41	6896.3	8088.15	7192.59	6221.48	ADL 32 × ADL 36	44.05	47.82	45.15	46.66	42.88
EXL 02 × ADL 39	5457.04	7687.41	8114.08	6308.89	6699.26	EXL 02 × ADL 39	39.41	47.53	41.66	47.92	42.37
EXL 06 × ADL 39	6297.04	6797.04	7457.04	7980	6740	EXL 06 × ADL 39	46.24	51.93	43.35	48.59	41.17
EXL 15 × EXL 04	6625.18	7620	7049.63	6868.15	6558.52	EXL 15 × EXL 04	39.89	44.65	43.40	48.03	37.98
EXL 01 × EXL 05	5691.11	8231.85	7191.11	6037.78	6480	EXL 01 × EXL 05	34.70	50.54	37.89	43.25	43.80
LY1001-22	6401.48	8102.96	7698.52	6855.56	5885.18	LY1001-22	35.93	36.99	31.58	37.28	37.64
LY1001-23	8046.67	6684.44	8301.48	8588.15	8477.04	LY1001-23	36.80	37.83	39.89	36.68	40.61
Oba Super 2	4514.81	6125.93	6140	6909.63	5660.74	Oba Super 2	42.65	50.86	40.03	48.44	46.19
		P > F						P > F			
LSD N	674.36	0.0001				LSD N	3.02	0.0001			
LSD VAR	904.75	0.001				LSD VAR	4.05	0.0001			
LSD N X V	ns	0.48				LSD N X V	ns	0.81			

Table 4. Effects of N-levels on the normalised difference vegetation index values of maize hybrids

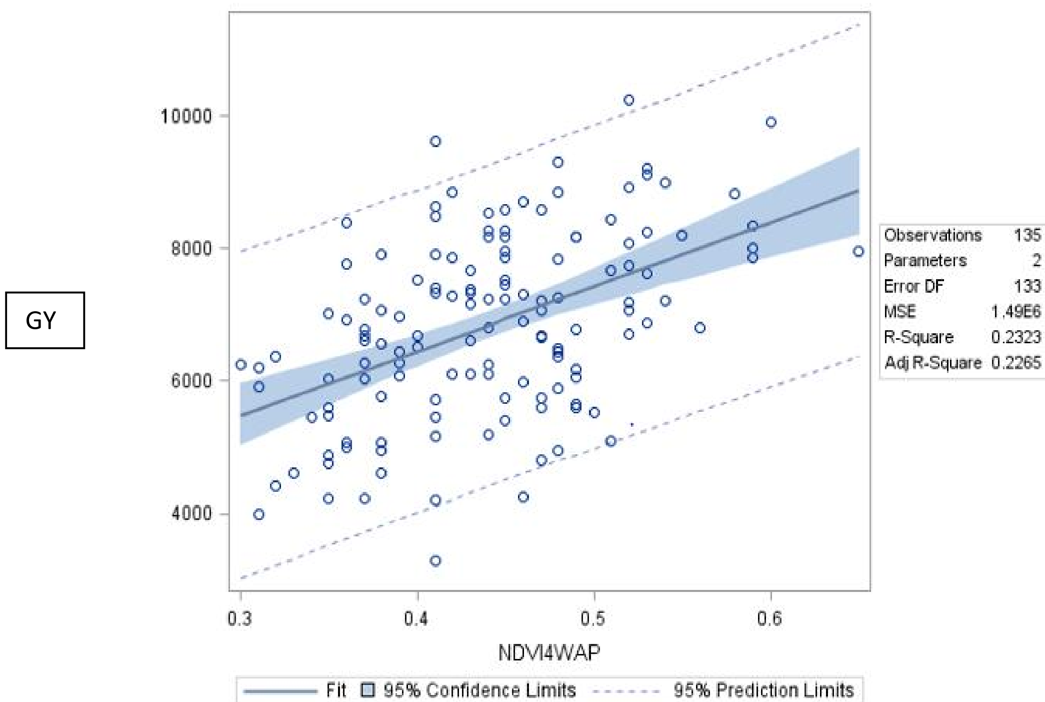
Hybrid	N LEVEL (kg N/ha)				
	0	80	100	120	140
		NDVI 2 weeks after planting			
ADL 32 × ADL 35	0.24	0.28	0.26	0.23	0.24
ADL 32 × ADL 36	0.25	0.30	0.28	0.27	0.26
EXL 02 × ADL 39	0.24	0.30	0.28	0.26	0.27
EXL 06 × ADL 39	0.25	0.29	0.27	0.27	0.28
EXL 15 × EXL 04	0.25	0.29	0.27	0.27	0.25
EXL 01 × EXL 05	0.25	0.30	0.26	0.25	0.25
LY1001-22	0.25	0.31	0.30	0.26	0.28
LY1001-23	0.25	0.30	0.28	0.29	0.26
Oba Super 2	0.27	0.28	0.28	0.28	0.28
		P > F			
LSD N()	0.02	0.0001			
LSD VAR	0.02	0.05			
LSD N X V	ns	0.99			
		NDVI 3 weeks after planting			
ADL 32 × ADL 35	0.37	0.35	0.37	0.37	0.37
ADL 32 × ADL 36	0.35	0.35	0.37	0.35	0.37
EXL 02 × ADL 39	0.37	0.37	0.41	0.39	0.37
EXL 06 × ADL 39	0.35	0.39	0.41	0.38	0.38
EXL 15 × EXL 04	0.35	0.36	0.35	0.33	0.40
EXL 01 × EXL 05	0.33	0.38	0.37	0.36	0.34
LY1001-22	0.39	0.45	0.45	0.39	0.38
LY1001-23	0.41	0.37	0.42	0.46	0.41
Oba Super 2	0.39	0.38	0.41	0.39	0.42
		P > F			
LSD N	0.02	0.01			
LSD VAR	0.03	0.0001			
LSD N X V	ns	0.28			
		NDVI 4 weeks after planting			
ADL 32 × ADL 35	0.42	0.40	0.44	0.44	0.42
ADL 32 × ADL 36	0.35	0.40	0.44	0.46	0.48
EXL 02 × ADL 39	0.37	0.44	0.49	0.47	0.46
EXL 06 × ADL 39	0.34	0.37	0.42	0.46	0.50
EXL 15 × EXL 04	0.40	0.38	0.42	0.43	0.50
EXL 01 × EXL 05	0.34	0.42	0.43	0.43	0.46
LY1001-22	0.46	0.42	0.56	0.49	0.46
LY1001-23	0.46	0.40	0.52	0.55	0.49
Oba Super 2	0.40	0.44	0.46	0.49	0.47
		P > F			
LSD N	0.03	0.0001			
LSD VAR	0.04	0.0009			
LSD N X V	ns	0.27			

As a result of the magnitude of the correlation coefficient between NDVI at 4 WAP and grain yield, regression analysis was computed between these two parameters. Fig. 1 shows the simple linear regression analysis between NDVI 4 WAP and GY while Fig. 2 shows a scatter plot and the predicted value for GY using the (Y = a + bX) regression equation, where Y is GY. For every possible change in value of X which is NDVI 4 WAP, GY = 2592.5 + 9653.5 x (NDVI 4 WAP), R^2 (coefficient of determination) = 0.23 and RMSE (Root mean square error) = 1222.3. From the generated regression equation, 2592.5 is the intercept 'a' where the regression cuts the y axis when x (NDVI 4 WAP) = 0, and 9653.5 is the regression coefficient b. The equation shows that an increase in NDVI values will result in an increase in GY because the regression coefficient is positive.

The correlation between NDVI values at 2, 3 and 4 and the total biomass is presented in Table 7; the correlation coefficient was positive between all the weeks of NDVI recording and biomass though the coefficient between NDVI 2WAP and total biomass was not significant. NDVI 4 WAP had the highest correlation with total biomass (r = 0.50; $P \leq 0.0001$).

Table 5. Effects of N-levels on the total biomass of maize hybrids

Hybrid	N level				
	0	80	100	120	140
	Total biomass (kg/ha)				
ADL 32 × ADL 35	15897.8	17413.4	19542.0	18707.2	16240.5
ADL 32 × ADL 36	14438.3	18192.5	21762.7	19030.2	18938.6
EXL 02 × ADL 39	19095.1	19942.1	24449.7	16062.6	20113.6
EXL 06 × ADL 39	17035.2	15967.2	23045.6	19552.7	20702.9
EXL 15 × EXL 04	20327.0	20593.7	19872.3	17002.2	24149.4
EXL 01 × EXL 05	20379.1	20892.0	24376.3	17214.7	18248.9
LY1001-22	22698.9	30191.0	31532.0	24359.2	20074.5
LY1001-23	28256.2	21924.7	26418.3	30917.0	26368.1
Oba Super 2	13115.7	15207.6	19414.1	18414.2	15305.2
		P > F			
LSD N	2495.3	0.01			
LSD VAR	3347.8	0.0001			
LSD N X V	ns	0.47			



NDVI4WAP = Normalised vegetation index at 4 weeks after planting; GY = Grain yield per hectare.

Fig. 1. Simple linear regression analysis between NDVI 4WAP and GY

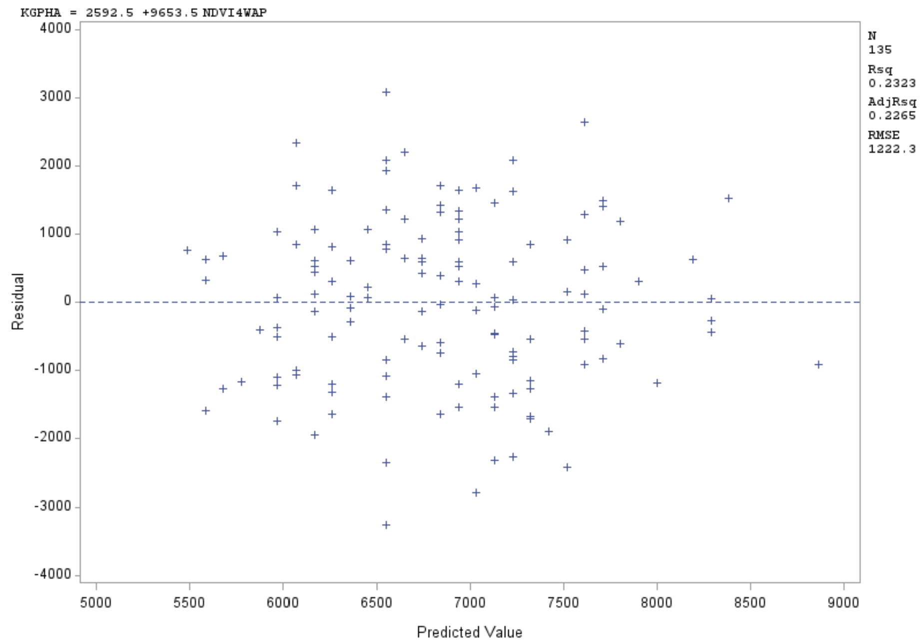


Fig. 2. Scattered plot diagram between GY and NDVI4WAP

Table 6. Pearson correlation coefficients (r) between evaluated parameters and yield per hectare

Parameter	R
NDVI 2 WAP	0.24^{**}
NDVI 3 WAP	0.36^{***}
NDVI 4 WAP	0.48^{***}
Plant height at 4WAP	0.39^{***}
Plant height 5WAP	0.40^{***}
Plant height 6WAP	0.38^{***}
Plant height 7WAP	0.41^{***}
Plant height 10WAP	0.30^{**}
Number of leaves at 4WAP	0.27^{**}
Number of leavesat5WAP	-0.05^{ns}
Number of leavesat6WAP	-0.01^{ns}
Number of leavesat7WAP	0.28^{**}
Number of leavesat10WAP	-0.09^{ns}
Cob weight	0.89^{***}
Harvest index of cob	0.08^{ns}
Harvest index of grain	0.10^{ns}

Table 7. Pearson correlation coefficients (r) between NDVI values and total biomass per hectare

NDVI	R
NDVI2WAP	0.12^{ns}
NDVI3WAP	0.48***
NDVI4WAP	0.45***

4. DISCUSSION

The importance of nitrogen in maize production had been well documented globally [17]. In Nigerian agriculture, the importance of nitrogen for optimum maize production has also long aroused the attention of several studies [18,19,20,21]. However, recently, concerns have been raised on the uncontrolled use of the chemical source of N because of its polluting effect on groundwater [22]. Hence the need to evaluate various N-levels for appropriateness in maize production.

Influence of nitrogen levels and maize hybrids was found to be significant for all the growth parameters of maize. These results oppose the findings of LeGouis et al. [23] and Imran et al. [24] who reported that nitrogen had little or no significant effect on maize growth. Plots that received 100 kg Nha^{-1} produced the maximum growth parameters and these results are in line with Amanullah et al. [25] who stated that maize favours vegetative growth with an increase in N application. Similarly, it agrees with the observations of Onasanya et al. [4] who reported that fertiliser application resulted in luxuriant growth. Good vegetative establishment is a precursor to high yields as indicated by the positive correlation between the plant heights and the achieved yields. This observation was affirmed by Bray and Bailey-Serres [26] who indicated that high number of leaves on fertiliser treated plants contributed to high yields. On the contrary, the negative and non-significant correlation between the number of leaves and the final yield might indicate that when nitrogen becomes too available in the soil, vegetative growth becomes favoured at the expense of assimilate channeling towards grain production this agrees with Wajid et al. [27] who concluded that higher nitrogen level influence biomass production.

The evaluated hybrids responded differently to the evaluated N rates with LY1001-23 producing the overall highest yield; the result of this experiment agreed with the findings of Ogundare et al. [7], Balasubraminian et al. [28], Roy and Singh [29] and Ogundare [30]. They reported significant responses of some maize varieties to nitrogen in grain yield.

The low relationship between NDVI values at 2 and 3 WAP indicates that GY of maize may not be a function of the biomass of the plant at early stages of the crop. Elazab et al. [31], Vergara-Diaz et al. [32] and Vergara-Díaz et al. [2] had reported that increase in leaf area does not result in a corresponding increase in NDVI values and therefore the relationship between NDVI values and GY worsened. However, the significant NDVI values obtained implies that the trapped energy were used for vegetative growth which aid good photosynthetic activities thereby increasing the eventual yield. A simple regression equation is used to obtain and explain the grain yield using NDVI at 4 WAP. Significant NDVI values obtained implies that trapped energy were used for vegetative growth which; this finding agrees with the work of Jingfeng et al. [33] that worked on rice and reported that high NDVI values significantly correlates with final yield. Furthermore, the derived regression equation predicts that an increase in NDVI values will produce an increase in grain yield of maize. In addition, Adebayo et al. [34] found out that high potential for green biomass accumulation at the seedling stage by maize hybrids may be predictive of high grain yielding potential.

5. CONCLUSION

The present study investigated the effect of nitrogen rates on some growth and yield parameters of maize. The finding reveals that application of nitrogen influenced plant growth and yield. Among the levels of urea used in this experiment 140 kg Nha^{-1} improved growth and yield of the hybrids the most with hybrid LY1001-23 having the highest yield potential. Also, remote sensing technique can be further evaluated for possible use in predicting the grain yield of maize and other cereal crops through their vegetative performance at early stages. The findings of the present study are preliminary and further studies are being conducted to validate these results.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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