

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

ABSTRACT

Aims: To determine the quantity of nitrogen required for vegetative, yield and yield components of maize and to predict these attributes using the Normalized Difference Vegetative Index

Study design: Experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times

Place and Duration of Study: Sample: LAUTECH Teaching and Research Farm between June and October, 2015

Methodology: Seeds of eight maize hybrids and Oba Super 2 (local check) obtained from IITA Ibadan were evaluated with five nitrogen rates (0, 80, 100, 120 and 140 kg N/ha). Seeds were sown in two 5 m row plots with 0.75 m space between rows and 0.5 m within rows. Data was collected on Normalized Difference Vegetation Index (NDVI) at 2, 3 and 4 weeks after planting (WAP), number of leaves, plant height, cob weight, grain weight, harvest index of cob and grain were subjected to analysis of variance

Results: Analysis of variance 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, regression analysis was computed between these two parameters; for every possible change in value of NDVI 4 WAP, the corresponding equation for GY is $2592.5 + 9653.5 (\text{NDVI } 4\text{WAP})$

Conclusion: The study concluded that application of 140 kg N/ha nitrogen fertilizer improves yield and yield components of maize. Moreover, judicious application of remote sensing (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]. 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 [2]. 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 [3]. Nitrogen is an essential plant nutrient and a major yield-determining nutrient for maize [4]. 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 [5]. Hence, nitrogen is the driver of plant growth and it makes up about 4% of dry matter of plants [6].

Generally, crops grown on N-deficient soils exhibit distinctive N-deficiency symptom including poor growth, chlorosis and disordered physiological and biochemical attributes. 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 utilization of such land is only successful for a limited period. Thereafter, subsequent cropping requires additional fertilizer use.

The results of several nutrient requirement researches conducted in Nigeria have resulted to fertilizer recommendations that gave blanket requirements for maize in different ecologies [7]. This practice aims at giving farmers a fairly appreciable economic return from fertilizer 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 fertilizer 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. The Greenseeker handheld optical sensor unit [8] is a spectroradiometer that has been proposed for phenotyping in maize adaptation [9]; it is used to measure normalized difference vegetation index (NDVI). NDVI measurements uses numerical indicator to analyze remote sensing measurements and has been described to be highly correlated with grain yield in maize and other crops [9 10]. 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 [9; 11]. 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.

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 08° 10' N and 04° 10' E, and elevation 1,286 m above sea level with average annual rainfall of 1,000 mm [12].

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 (2) plants per stand at two (2) weeks after planting (WAP) to give 53,333 plants/ha. 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-bipyridinium 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 weight (GW) obtained by shelling all ears harvested from each plot and a representative grain sample was taken to determine percent moisture. GW 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 Normalized Difference Vegetation Index (NDVI) measurement

The Green Seeker Handheld Optical Sensor Unit [8], installed with red sensor, red waveband centered at $650 \pm 10 \text{ nm}$, and near infra-red (NIR) band centered at $770 \pm 15 \text{ nm}$, 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

Collected data were subjected to analysis of variance (ANOVA) using the Procedures for General Linear Model (PROC GLM) in SAS [13]. 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 [13].

3. RESULTS

3.1 Plants Height and Number of Leaves of Maize

The height of maize plant as influenced by maize varieties and N-levels is presented in Table 2. Similarly to the influence on NDVI values, maize hybrids and the levels of N significantly ($P \leq 0.01$) affected the height of maize plants. 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) 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 level. Generally, the interaction between the maize varieties and the N-levels was not significant for plant height at all weeks of measurement.

Presented in Table 3 are the effects of maize hybrid and N-levels on the number of leaves of maize, as observed in the previous parameters, maize hybrid and N-levels significantly ($P \leq 0.01$) influenced the number of leaves of maize. 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 average number of leaves obtained from LY1001-23 at the same application rate.

3.2 Yield of Maize

Yield and yield parameters of maize as influenced by hybrid and N-levels are presented on Table 4. The evaluated yield parameters were significantly ($P \leq 0.01$) influenced separately by hybrid and N-levels but no interaction was observed. 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) occurred on EXL 01 x EXL 05 at 140 kg N/ha⁻¹ while the least (320.67 kg/ha) was obtained on unfertilized EXL 02 x 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 x ADL 39 at 80 kg N/ha⁻¹ while the least value (28.29) occurred on EXL 01 x EXL 05 that received no fertilizer though this was not significantly different from the values recorded from unfertilized LY1001-22 and LY1001-23. Furthermore for GY, LY1001-23 produced the highest yield (8588.15 kg) at 140 kg N/ha⁻¹ while the least value (4514.81 kg) was produced by Oba Super 2 at 0 kg N/ha⁻¹.

3.3 Normalized Difference Vegetation Index of Maize

The effects of N-levels and maize varieties on the NDVI values of maize plants is presented in Table 1; N-levels and maize varieties significantly ($P \leq 0.01$) influenced the NDVI values throughout the period of recording. At 2 WAP, application of 80 kg N ha⁻¹ consistently produced

the highest NDVI values across the maize varieties but the values were not significantly different from the values produced by application of 100 kg N ha⁻¹ while plots that received no fertilizer 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 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 x ADL 39 and EXL 01 x EXL 05 planted without application of N fertilizer. The interaction between the maize hybrids and the N-levels was not significant for the NDVI values all through the observation period.

3.4 Trait correlation and regression

Table 5 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.

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; Figure 1 shows the simple linear regression analysis between NDVI 4 WAP and GY while Figure 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, $GY = 2592.5 + 9653.5$ (NDVI 4WAP), 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 4WAP) = 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.

4.0 DISCUSSION

The importance of nitrogen in maize production had been well documented globally [14]. In Nigerian agriculture, the importance of nitrogen for optimum maize production has also long aroused the attention of several studies [15], [16], [17] and [18]. However, recently, concerns have been raised on the uncontrolled use of chemical source of N because of its polluting effect on groundwater [19]. Hence the need to evaluate various N levels for appropriateness in maize production.

Influence of nitrogen levels and maize varieties was found to be significant for all the growth parameters of maize. These results opposes the findings of [20] and [21] who reported that nitrogen had little or no significant effect on maize growth. Plots that received 100 kg N/ha⁻¹ produced the maximum growth parameters and these results are in line with [22] who stated that maize favours vegetative growth with increase in N application. Similarly, it agrees with the observations of [3] who reported that fertilizer 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 [23] who indicated that high number of leaves on fertilizer 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 [24] 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 [25], [26], [27] and [6]. They reported significant responses of some maize varieties to nitrogen in grain yield.

A simple regression equation is used to obtain and explain the grain yield using NDVI at 4 weeks after planting. Significant NDVI values obtained implies that trapped energy were used for vegetative growth which aid good photosynthetic activities thereby increasing the eventual yield; this finding agrees with the work of [28] that worked on rice and reported that high NDVI values significantly correlates with final yield.

Furthermore, the derived regression equation predicts that increase in NDVI values will produce an increase in grain yield of maize. In addition, [29] found out that high potential for green biomass accumulation at the seedling stage by maize hybrids may be predictive of high grain yielding potential.

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 N/ha 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 used to predict the grain yield of maize and other cereal crops through their vegetative performance at early stages.

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189 Table 1: Effects of N-levels on the Normalized 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
LSD N	0.02				
LSD VAR	0.02				
LSD N X V	ns				
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
LSD N	0.02				
LSD VAR	0.03				
LSD N X V	ns				
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
LSD N	0.03				
LSD VAR	0.04				
LSD N X V	ns				

190 Table 2: 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
LSD N	1.37					LSD N	3.63				
LSD VAR	1.84					LSD VAR	4.87				
LSD N X V	ns					LSD N X V	Ns				
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
LSD N	2.36					LSD N	5.12				
LSD VAR	3.17					LSD VAR	6.88				
LSD N X V	ns					LSD N X V	ns				

191 Table 3: Effects of N-levels on the number of leaves of maize hybrids

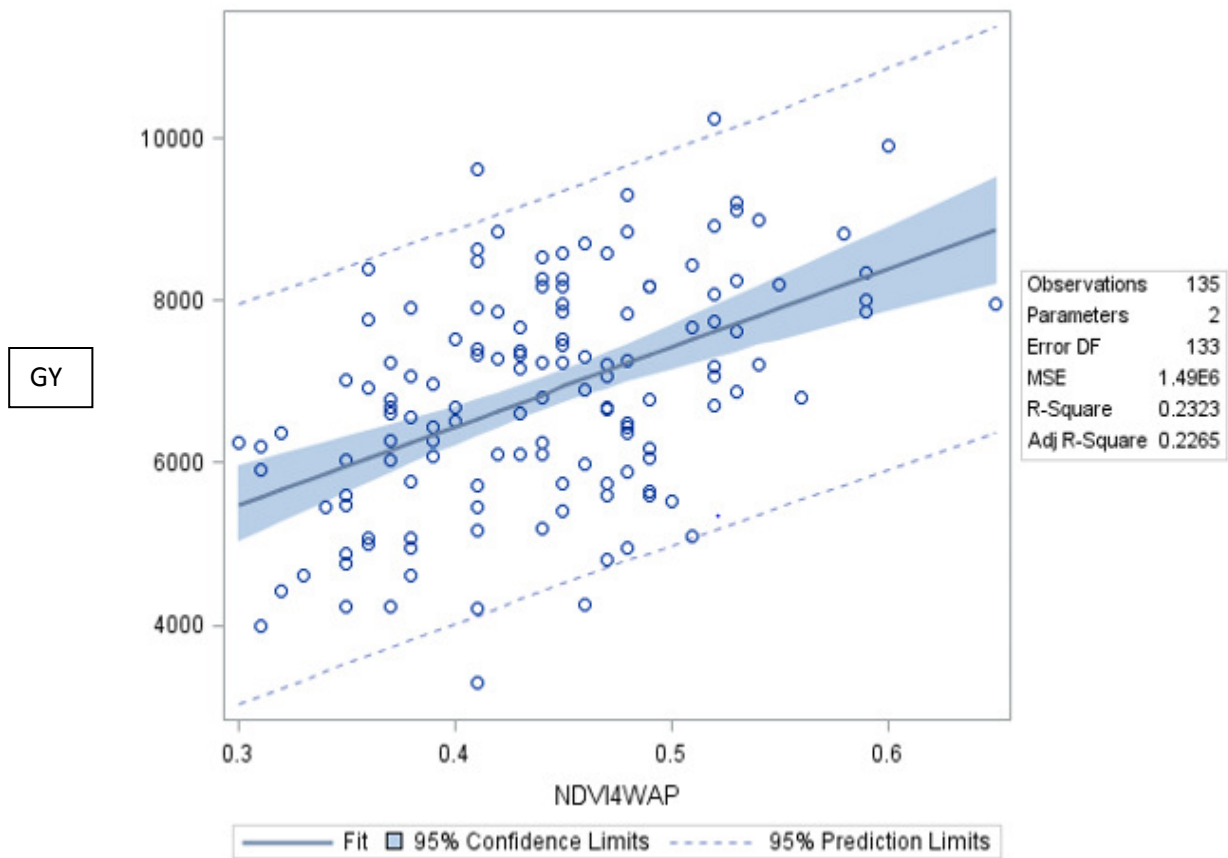
Hybrid	N LEVEL kg N/ha					Hybrid	N LEVEL kg N/ha				
	0	80	100	120	140		0	80	100	120	140
Number of leaves 4 Weeks After Planting						Number of leaves 6 Weeks After Planting					
ADL 32 × ADL 35	5.00	6.78	4.44	7.67	5.89	ADL 32 × ADL 35	7.11	9.78	9.55	8.67	9.11
ADL 32 × ADL 36	4.89	6.89	4.11	7.89	6.11	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
LSD N	0.36					LSD N	0.44				
LSD VAR	0.48					LSD VAR	0.59				
LSD N X V	Ns					LSD N X V	ns				
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
LSD N	0.37					LSD N	0.49				
LSD VAR	0.49					LSD VAR	0.65				
LSD N X V	Ns					LSD N X V	0.32				

192 Table 4: Effects of N-levels on the yield parameters of maize hybrids

Hybrid	N LEVEL					Hybrid	N LEVEL				
	0	80	100	120	140		0	80	100	120	140
	CW (kg/ha)						HIG				
ADL 32 × ADL 35	332.67	464.00	530.67	598.00	465.00	ADL 32 × ADL 35	34.38	42.31	36.05	36.14	35.93
ADL 32 × ADL 36	411.33	525.00	471.00	479.67	487.67	ADL 32 × ADL 36	34.85	38.1	37.64	38.08	34.41
EXL 02 × ADL 39	320.67	569.00	560.00	475.00	436.67	EXL 02 × ADL 39	29.44	38.64	33.22	39.44	34.2
EXL 06 × ADL 39	582.67	532.33	494.00	646.33	511.67	EXL 06 × ADL 39	37.12	42.87	33.68	40.86	32.09
EXL 15 × EXL 04	484.33	537.00	533.00	528.33	455.67	EXL 15 × EXL 04	32.32	36.89	35.63	40.33	30.67
EXL 01 × EXL 05	344.67	519.00	476.67	570.00	648.67	EXL 01 × EXL 05	28.29	41.93	30.15	35.36	36.16
LY1001-22	408.67	478.00	468.67	525.33	451.67	LY1001-22	28.44	27.83	24.46	29.23	28.92
LY1001-23	502.00	494.67	516.67	624.33	595.33	LY1001-23	28.43	30.49	31.44	28.36	32.22
Oba Super 2	440.33	421.00	494.67	544.33	514.33	Oba Super 2	34.45	40.7	31.63	38.17	36.31
LSD N	53.99					LSD N	2.7				
LSD VAR	72.43					LSD VAR	3.62				
LSD N X V	Ns					LSD N X V	ns				
	GY (kg/ha)						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	6896.30	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	7980.00	6740.00	EXL 06 × ADL 39	46.24	51.93	43.35	48.59	41.17
EXL 15 × EXL 04	6625.18	7620.00	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	6480.00	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	6140.00	6909.63	5660.74	Oba Super 2	42.65	50.86	40.03	48.44	46.19
LSD N	674.36					LSD N	3.02				
LSD VAR	904.75					LSD VAR	4.05				
LSD N X V	ns					LSD N X V	ns				

193 Table 5: Pearson correlation coefficients (r) between evaluated parameters and yield per hectare

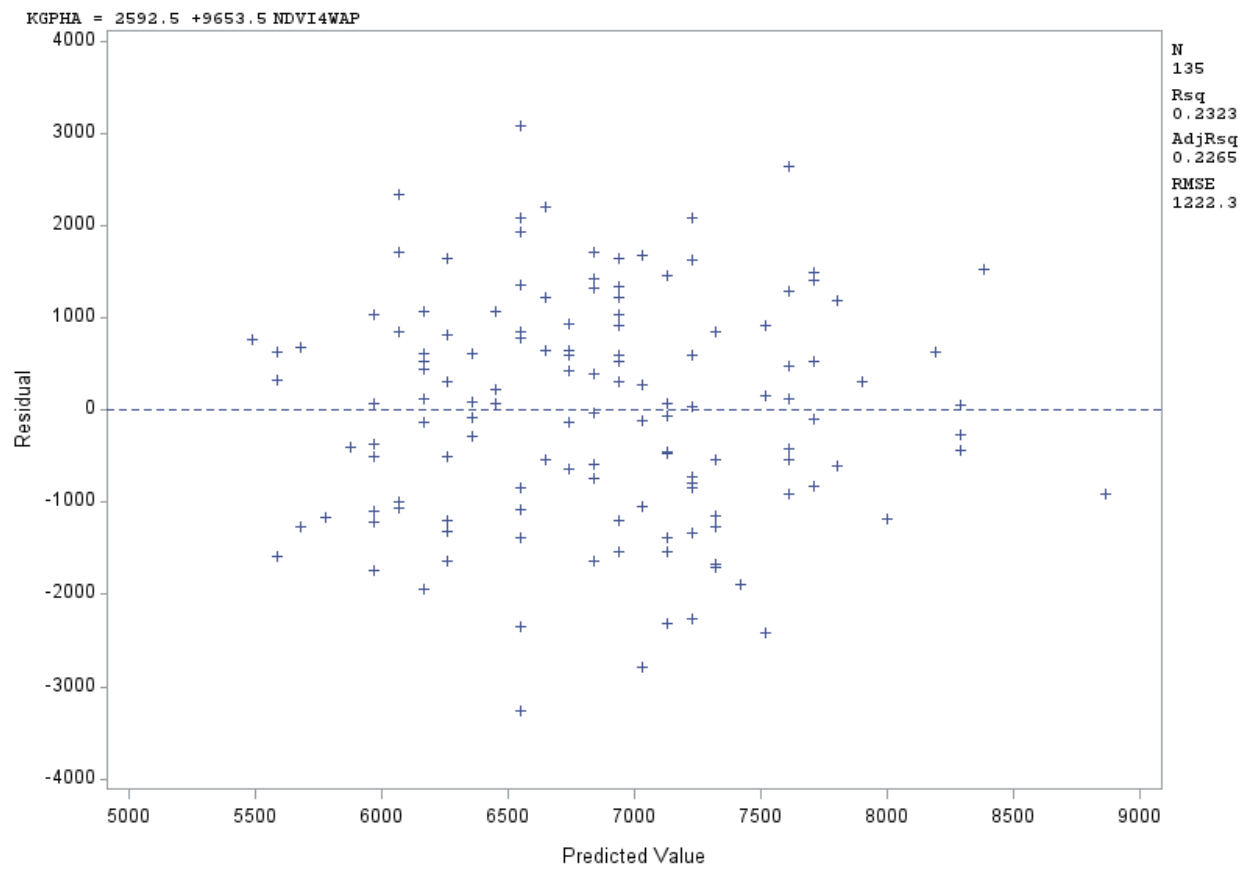
Parameter	r
NDVI 2 WAP	0.24 ^{**}
NDVI 3 WAP	0.36 ^{***}
NDVI 4 WAP	0.48 ^{***}
Ht 4WAP	0.39 ^{***}
Ht 5WAP	0.40 ^{***}
Ht 6WAP	0.38 ^{***}
Ht 7WAP	0.41 ^{***}
Ht 10WAP	0.30 ^{**}
NOL 4WAP	0.27 ^{**}
NOL 5WAP	-0.05 ^{ns}
NOL 6WAP	-0.01 ^{ns}
NOL 7WAP	0.28 ^{**}
NOL 10WAP	-0.09 ^{ns}
CWR	0.89 ^{***}
GWR	0.99 ^{***}
TBS	0.35 ^{***}
CWS	0.43 ^{***}
GWS	0.42 ^{***}
HIC	0.08 ^{ns}
HIG	0.10 ^{ns}



194

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

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



198

199 Figure 2: Scattered plot diagram between GY and NDVI4WAP