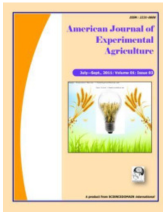

American Journal of Experimental Agriculture
5(2): 148-155, 2015, Article no.AJEA.2015.017
ISSN: 2231-0606

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Nitrogen Use and Assimilate Partitioning Ability for Grain Yield in Some Selected Maize (*Zea mays L.*) Inbred Lines Genotypes

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AOO and SOA designed the study and performed the statistical analysis. Both the authors wrote the first draft of the manuscript and managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEA/2015/12699
Editor(s):
(1) Masayuki Fujita, Dept. of Plant Sciences, Faculty of Agriculture, Kagawa University, Japan.
Reviewers:
(1) Anonymous, University of the Punjab, Pakistan.
(2) Anonymous, Biotechnology And Nuclear Agriculture Research Institute, Ghana.
Peer review History: http://www.sciencedomain.org/review-history.php?iid=665&id=2&aid=6091

Original Research Article

Received 14th July 2014
Accepted 7th August 2014
Published 13th September 2014

ABSTRACT

Breeding for high grain yield in maize under natural soil Nitrogen condition is of high importance to reduce the heavy usage of nitrogen base fertilizer to enhance productivity and encourage safety of the environment and consumer health. Nine maize inbred lines viz; 1393, KU1414, 5057, 5012, 9030, 9450, SW1, SW6 and SW4, were characterized in a field experiment under natural soil nitrogen 1.81 g/kg. Data were collected on plant growth parameters (plant height, number of leaves, leaf area and stem girth); phenology (percentage emergence, day to anthesis, day to silking and days to grain harvest); total nitrogen uptake and yield (plant wet weight, plant dry matter, cob weight and total seed weight). Parameters were paired and correlated to determine their relationships patterns. Positive relationships were obtained from all paired intra-parameter correlations from plant growth, phenology and yield, and from paired inter-parameter correlations between plant growth and yield. Negative relationships were obtained for paired inter-parameter correlations between phenology and growth and between phenology and yield. Total nitrogen

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uptake gave positive correlations with all parameters. Relative performance grouping analysis revealed that maize genotype 1393 had high n-uptake, high assimilate partitioning and high performance in Plant wet weight, cob weight and plant dry matter at grain harvest. KU1414, 5057 and 9030 had high n-uptake, low assimilate partitioning and low performance in plant wet weight, cob weight and plant dry matter at grain harvest . 5012 had low n-uptake, low partitioning and high performance. 9450 had low n-uptake, low assimilate partitioning and low performance; and SW1, SW6 and SW4 had low n-uptake, high assimilate partitioning and high performance. Hence, 5012 and SW genotypes expressed efficient Nitrogen-use for high grain yield and better growth and phenological performances.

Keywords: Nitrogen uptake; maize; genotype; inbred line; phenology; correlation analysis; performance.

1. INTRODUCTION

Crop varieties are grown under a wide range of climatic, weather and edaphic conditions [1]. Nitrogen nutrient as a component of edaphic factors within an agro-ecology plays a vital role in the growth, development and yield of agricultural plants. Nitrogen nutrient has been reported to be a major limiting factor in maize production and grain yield [2]. This nutrient shortage reduces crop performance in that it is an essential component of plants nucleic acids (DNA & RNA) and a major component of chlorophyll, the photosynthetic structure for carbohydrate formation and an important factor for dry matter production [3]. Though Nitrogen is relatively abundant in nature, about 78% is in the atmosphere and relatively small proportion of this is readily incorporated into the soil through atmospheric and biological fixation. Soil gains more Nitrogen from decaying materials and decomposition of domestic and industrial wastes. Nitrogen is deficient within the agro-ecology owing to its instability and rapid loss caused by huge transformations (n-cycle) involving mineralization, nitrification, denitrification, volatilization, run-off and leaching [4]. N problem is also caused by its limited availability for plant uptake only in form of Ammonium (NH_4^+) and Nitrate (NO_3^-) out of other forms such as nitrogen gas (N_2), ammonia (NH_3) and nitrite (NO_2^-). Research revealed N-nutrient depletion as a serious threat to crop yield and for profitable maize production [5-7]. Therefore optimum yield is hampered, because poor Nitrogen supply decreases dry matter accumulation, distribution and mobilization for economic yield [[8-10]. However, supplementary use of nitrogen base fertilizers to enhance maize productivity is not environment-friendly and high content residue in maize harvests is not safe for human health. Hence, breeding cultivars with high grain yield under natural soil Nitrogen condition is necessary. Therefore, this study focused on: (i) assessment of selected maize inbred lines on Nitrogen use for growth and development; (ii) characterization of maize lines on source-sink capacity for Nitrogen utilization; (iii) identification of maize lines with good N-utilization efficiency and better assimilates partitioning for high grain yield.

2. MATERIALS AND METHODS

The research field experiment was carried out on Practical Year Training Programme Farm, Faculty of Agriculture and Forestry, University of Ibadan (Lat. 7°27' 1.7'' North, 3° 53' 35.8'' East; average max temp. 33°C and min temp. 28°C; relative humidity 78%; annual rainfall >1000 mm). Soil samples were collected for total Nitrogen content determination using Kjedahl method after land clearing at surface and sub-surface at depth range 0-15 cm and 15-30 cm respectively. Nine inbred lines as shown in Table 1 were planted out in four replicates in a randomized complete block design. Each line was observed on varietal responses to N-uptake, mobilization and partitioning and yield performance according to the laboratory procedure of Kjedahl.

Table 1. List of the maize inbred line seeds and their description

Lines	Source	Name	Type
L1	IITA	1393	White
L2	IITA	KU1414	Yellow
L3	IITA	5057	White
L4	IITA	5012	White
L5	IITA	9030	White
L6	IITA	9450	Yellow
L7	LAUTECH	SW1	Yellow
L8	LAUTECH	SW6	White
L9	LAUTECH	SW4	White

Data were collected on parameters of growth (plant height, number of leaves, leaf area and stem girth); phenology (percentage emergence, day to anthesis, day to silking and day to green harvest); total nitrogen uptake and yield (plant wet weight, plant dry matter, cob weight and total seed weight) (Table 3) and subjected to analysis of variance using Statistical Analysis System (SAS, 19.0), the means were separated using Least Significant Difference (LSD) test at 0.05 degree of freedom. The parameters were paired for correlation analysis to determine their relationship patterns using the following formular;

$$r = 1/n - 1 \sum \frac{(X-\mu x)(Y-\mu y)}{\sigma x \sigma y}$$

where, r = correlation coefficient
n = sample size
X and Y are the two variables
x = change in X
y = change in Y

Relative performance score analysis was used to group inbred lines genotypes based on n-uptake, assimilate partitioning and performance.

3. RESULTS AND DISCUSSION

Anthesis is one of the most important periods for the diagnosis of nutritional status of maize in respect to nitrogen and other mineral nutrients that determine yield generating effect of nitrogen. This came up from the fact that plant nutritional status at this growth stage affects the photosynthetic activity of leaves after anthesis, and consequently, the length of the grain filling stage [11].

From the result of the experiments in Table 2, which revealed that Line L1 (1393) had the highest stem nitrogen percentage (5.23%) at anthesis followed by line L2 (KU1414) with stem nitrogen percentage (4.47 %) and the least percentage value found in line L8 (SW6) (1.65 %). Line L2 had the highest leaf nitrogen percentage (13.50%) followed by line L1 (11.72 %) while line L9 (SW4) exhibited the least leaf nitrogen percentage (6.45%). This indicates that high nitrogen is being partitioned and accumulated in the leaf than in the stem at anthesis, and L1, L2, L3 and L5 has the ability to accumulate nitrogen and partitioned it than other lines tested. Hence, leaf serves as high assimilate bank to remobilize for grain filling at plant productive phase, therefore it is more a factor that determine seed yield in maize plant [12]. Also, plant yield parameters taken during anthesis and at harvest gave a mean value of 168.89g and 122.6g respectively for all the lines. This revealed that the plants had high plant wet weight at anthesis than at harvest; which may be ascribed to high moisture content in the plants due to active physiological processes during anthesis than at harvest stage. Also, plant dry matter at anthesis is relatively low with mean value of 25.00g for all the lines, compared to plant dry matter recorded after harvest with mean value of 56.85g. This was ascribed to high assimilate accumulation in the plants than moisture content at harvest stage, and the trait was expressed in each line with their respective genetic potentials. Plant total seed weight taken after harvesting gave a mean value of 45.99g for the lines, SW4 had highest value of 71.00g and 9450 had least value of 20.66g. This wide gap obtained from the lines indicated a clear cut for individual line genetic capacity to efficiently mobilize assimilates within plant system for grain yield. Correlation analysis as shown in Table 3 revealed that intra-parameter correlations from plant growth, phenology and yield gave positive relationships and significant correlations at $p \leq 0.05$ as indicated between respective plant height and number of leaf with coefficient value r=0.5185 (Fig. 1), days to silking and days to anthesis with coefficient value r=0.7094 (Fig. 2) and plant wet weight and cob weight with coefficient value r = 0.7797 (Fig. 3). Inter-parameter correlations from plant growth and phenology gave negative relationships as indicated between leaf areaand days to silking with coefficient value r = -0.7819 (Fig. 4); inter-parameter correlations from plant phenology and yield gave negative relationships as indicated between days to anthesis vs plant dry matter with coefficient value r = -0.3269 (Fig. 5), and inter-parameter correlations from plant growth and yield gave positive relationships as indicated between cob weight vs plant height with coefficient value r=0.5106 (Fig. 6). Correlation analyses revealed an increase in value of one paired of intra-parameters from growth, phenology and yield, and between one paired of inter-parameters from growth and yield will leads to proportional increase in the value of the other. Thus, negative and inverse relationships between pairs of inter-parameters from phenology and growth, and from phenology and yield indicated that increase in value of one paired parameters will leads to proportional decrease in the value of the other.

Relative performance score analysis for genotypes characterization (Table 4) revealed that genotype 1393 had high N-uptake, high assimilate partitioning and high performance values. This indicated a disadvantage (d) at high nitrogen demand. KU1414, 5057 and 9030 had high N-uptake, low assimilate partitioning and low performances. This indicated advantage at low nitrogen demand and disadvantage at poor performances. Genotype 9450 had low N-uptake, low partitioning and low performance, this indicated poor performances. Genotype 5012 had low N-uptake, low partitioning and high performance, this indicated advantage at low nitrogen demand and good performance. SW1, SW6 and SW4 had low N-uptake, high partitioning and high performance, this indicates a low nitrogen demand and good performance.

Table 2. Percentage nitrogen uptake at anthesis and yield parameters of the maize Inbred lines taken at anthesis and after grain harvest

	At anthesis					At harvest					
Lines	**SN%**	**LN%**	**TNU%**	**PWW**	**PDM**	**PWW**	**PDM**	**CBW**	**CBL**	**CBD**	**TSW**
L1	5.23	11.72	16.95	159	23.00	208.00	92.00	106.00	16.20	16.20	57.00
L2	4.47	13.50	17.97	170	25.00	117.60	48.50	65.20	14.30	14.30	41.33
L3	3.67	10.04	13.71	150	20.00	72.00	34.66	44.00	14.60	14.60	24.66
L4	3.75	8.26	12.01	155	30.00	88.80	44.66	69.00	14.60	14.60	58.66
L5	2.54	10.81	13.35	151	18.00	89.30	39.33	21.00	9.10	9.10	31.00
L6	2.26	9.98	12.24	160	26.00	99.70	34.50	53.30	14.50	14.50	20.66
L7	1.96	8.68	10.64	200	35.00	158.80	74.00	80.40	16.00	16.00	56.66
L8	1.65	6.66	8.31	165	24.00	119.50	64.00	97.50	14.30	14.30	52.66
L9	1.87	6.45	8.33	165	24.00	150.00	80.00	103.6	16.30	16.30	71.33
Mean	3.04	9.56	12.61	163.89	25.00	122.60	56.85	71.11	14.40	14.40	45.99

SN%-Stem nitrogen percentage; LN%-Leaf nitrogen percentage, CBL-Cob length; PWW- Plant wet weight; PDM- Plant dry matter; TSW-Total seed weight CBW- Cob weight; CDM- Cob dry matter

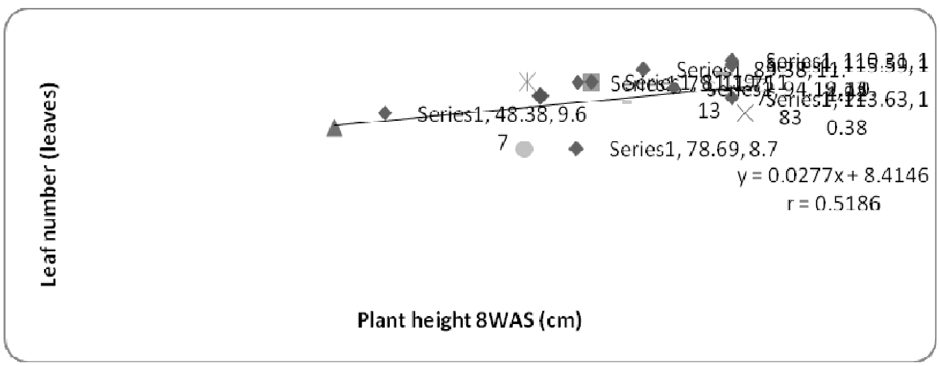

Fig. 1. Correlation graph obtained from plant height and leaf number parameters for the lines
r = correlation coefficient

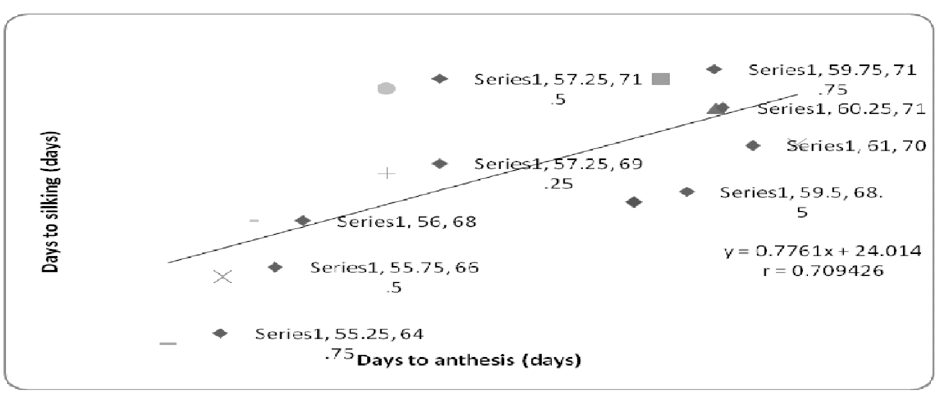

Fig. 2. Correlation graph obtained from days to anthesis and days to silking parameters for the lines
r = correlation coefficient

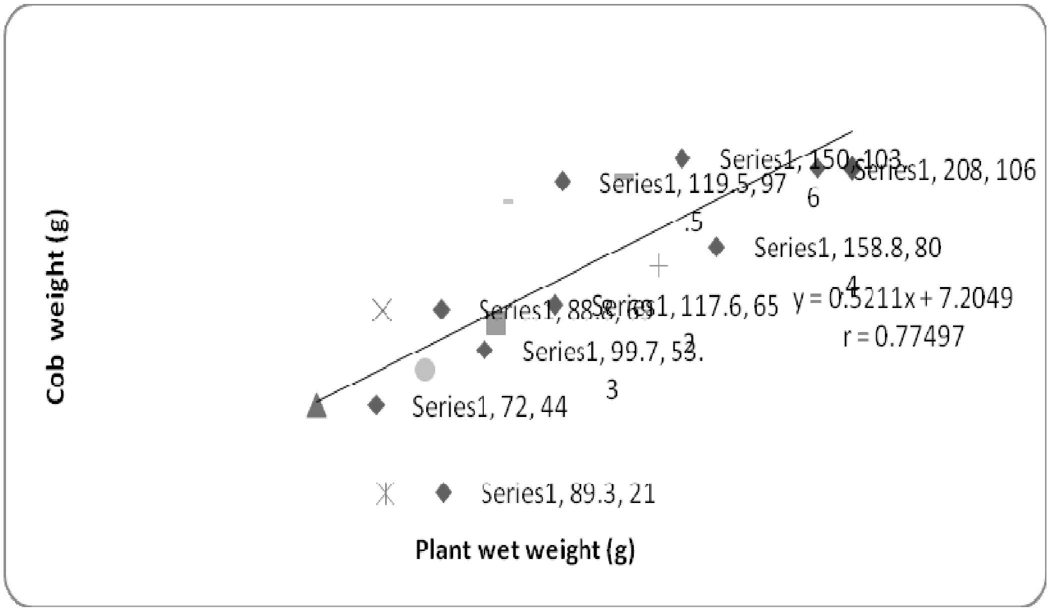

Fig. 3. Correlation graph obtained from plant wet weight and cob weight parameters for the lines
r = correlation coefficient

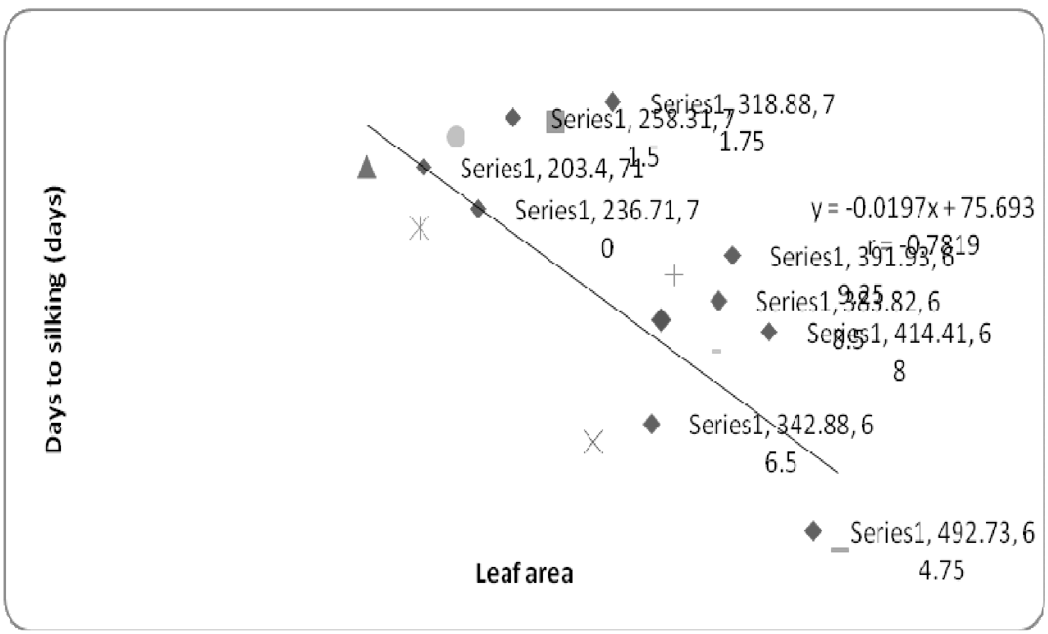

Fig. 4. Correlation graph obtained from leaf area and days to silking parameters for the lines
r = correlation coefficient

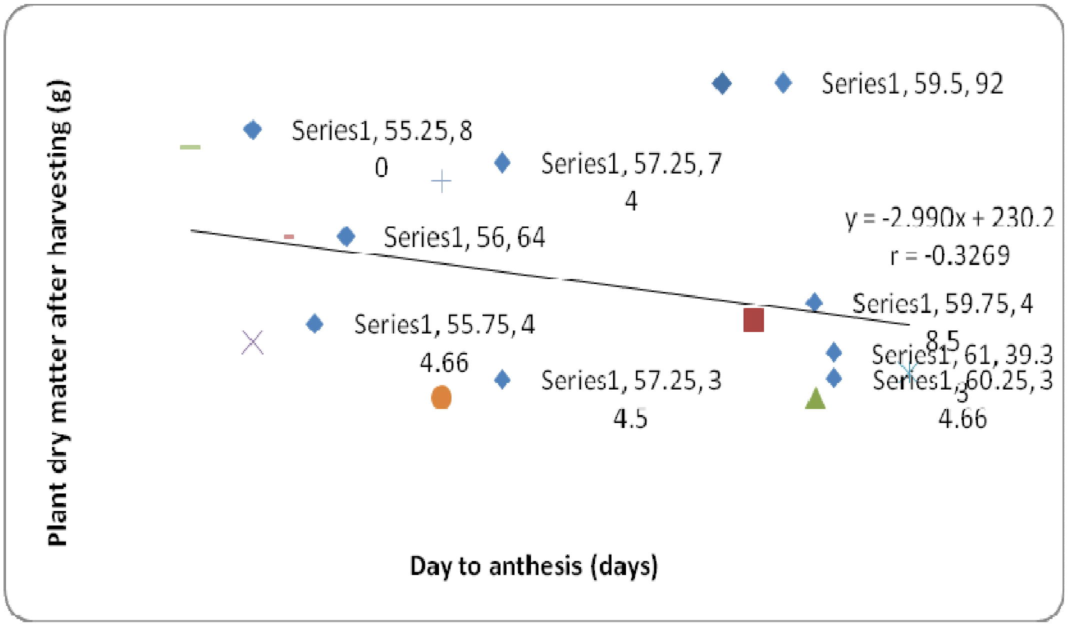

Fig. 5. Correlation graph obtained from day to anthesis and plant dry matter parameters for the lines
r = correlation coefficient

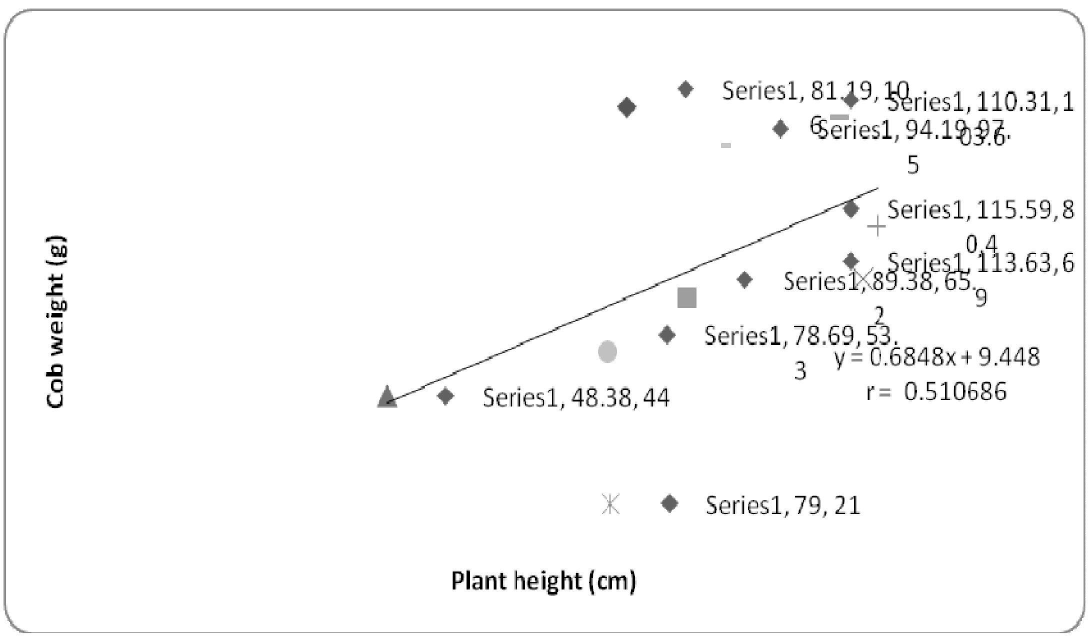

Fig. 6. Correlation graph obtained from plant height and cob weight parameters for the lines
r = correlation coefficient

Table 3. Correlation matrix of growth, phenology, nitrogen uptake and yield parameters for the lines

PHT	LA	LN	CL	DA	DS	DH	PWW	PDM	CW	TN	SW	
PHT	-											
LA	0.574	-										
LN	0.519	0.321	-									
CL	0.511	0.351	0.005	-								
DA	-0.527	-0.502	-0.003	-0.277	-							
DS	-0.421	-0.782*	-0.158	0.160	0.709*	-						
DH	-0.406	-0.305	0.004	0.025	0.594	0.422	-					
PWW	0.129	0.462	0.227	0.321	-0.071	-0.110	0.002	-				
PDM	0.539	0.406	0.004	0.295	-0.327	-0.036	-0.232	0.070	-			
CW	0.511	0.899*	0.095	0.624	-0.365	-0.390	0.007	0.778*	0.130	-		
TN	0.451	0.476	0.042	0.128	0.760*	0.601	0.695	0.101	0.248	0.271	-	
SW	0.788*	0.927*	0.643	0.530	0.617	0.861*	0.296	0.628	0.428	0.812*	0.353	-

** Correlation was significant at $p \leq 0.05$ level*

Table 4. Relative performance score obtained from lines characterization on plant growth, phenology, nitrogen content and yield parameters

Lines	PHT	LN	LA	SGT	DAT	DSK	DGH	EM %	PWA	PDA	PWH	CBW	CBH	SN%	LN %	TSW	RMS
L1	-	+	+	+	-	+	-	-	-	-	+	+	+	+	+	+	10*
L2	-	+	-	+	-	-	-	+	+	-	-	-	-	+	+	-	6
L3	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	3
L4	+	-	+	+	+	+	+	-	-	+	-	-	+	+	-	-	9*
L5	-	+	-	+	-	-	+	-	-	-	-	-	-	-	+	-	4
L6	-	-	-	-	+	-	+	-	-	+	--	-	+	-	+	-	5
L7	+	+	+	-	+	-	+	+	+	+	+	+	+	-	-	+	12*
L8	+	-	+	-	+	+	+	+	+	-	-	+	-	-	-	+	9*
L9	+	+	+	+	+	+	-	+	+	-	+	+	-	-	-	+	12*

PHT-Pant height, LN-Leaf number, LA-Leaf area, SGT-Stem girth, DAT-Days to anthesis, DSK-Days to silking, DGH-Days to green harvest, EM%-Percentage emergence, PWA-Plant weight at anthesis, PDA-Plant dry matter at anthesis, PWH-Plant weight after harvesting, CBW-Cob weight, CBH-Cob height, SN%-Stem nitrogen percentage, LN%-Leaf nitrogen percentage, TSW-Total seed weight
+ represents values above mean (8.78)
- represents values below the mean
** represents performance of lines above general average*

4. CONCLUSION

Breeding and characterization of genotypes for high grain yield under natural soil nitrogen condition is a feasible procedure and promising development to avert supplementary use of nitrogen base fertilizers to enhance maize productivity and profitable production. This study identified inbred lines 5012, SW1, SW6 and SW6 as good genotypes with efficient Nitrogen-use for high grain yield and good performance. These genotypes are recommended for use at improving farmers cultivated varieties to encourage maize cultivation with zero use of chemical fertilizers in order to preserve our environment and safeguard consumers' health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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