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Genetic Variability and Inter-relatedness of Agronomic Traits of Single Cross Hybrid Maize in Contrasting Soil Nitrogen-nutritional Conditions

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Authors' contributions

The idea of this work was conceived, designed and conducted by author DJO and also performed the statistical analysis, interpreted the data and wrote the first draft of the manuscript. Authors SAO and DKO read and approved the final manuscript.

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ABSTRACT

Background: Lowering the nitrogen demand is the most cost effective and sustainable option to increase grain yield of maize in poor fertility soil.
Aim: This study was conducted to estimate the variability and inter-traits' association of white and yellow hybrid maize in soil nitrogen-nutritional stress and optimal conditions.
Materials and Methods: 150 white and 66 yellow single cross hybrid maize were evaluated in contrasting soil (stress and optimal) N conditions in Ibadan in 2014 and 2015. The trial for the white maize was laid out in 19 × 8 lattice design while the yellow maize was experimented in randomized complete block design. Each trial was replicated three times. Data were collected on days to anthesis (DTA), days to silking (DTS), plant height (PH), ear height (EH), anthesis-silking-interval (ASI) and grain yield (GY) were estimated while leaf senescence (LS), plant aspect (PASP) and ear aspect (EASP) were scored. Data collected were subjected to analysis of variance while variances and broad sense heritability were calculated and rated.

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Results: Greater variability existed among white maize than the yellow maize for the traits. Inheritance of the traits can be predicted in optimal N than stress condition. Additive genes action was responsible for inheritance of DTA and DTS while both additive and non-additive control the GY, PH, EH and LS of the white maize in both N conditions. For yellow maize, the DTA and DTS were controlled by additive genes action in both N conditions. The GY, ASI, PH, EH and LS were governed by both additive and non-additive genes actions in N stress condition. Additive genes action is responsible for inheritance of PH and EH while both additive and non-additive actions govern inheritance of GY, ASI and LS in optimal condition. The GY had positive relationship with the DTA, DTS and LS in both N conditions for the white maize while the GY positively correlated with PH, EH and LS in N stress, but with ASI only in optimal condition for the yellow maize.
Conclusion: Grain yield, flowering, height and leaf senescence can be used in selecting maize for nitrogen-use-efficiency.

Keywords: Abiotic stress; correlation; hybrid maize; heritability; nitrogen-use.

1. INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop in the world that enhances food security, employment and income generation for small and larger families [1]. It is widely cultivated in Africa where it provides food for man, feed for livestock and raw materials for the industries. Soil nitrogen (N) is the most important plant nutrient that enhances productivity of the crop. Deficiency of the nutrient in the soil constitutes a major constraint to its sustainable production in Africa [2,3]. The nutrient is mobile in nature and so it is rapidly lost from the soil through leaching, volatilization, run off or crops uptake. Proposed remedies to reduce the constraints are expensive, thus the need to quest for maize improvement for efficient use of available soil nitrogen.

Genetic variability is a combination of estimates of genetic and environmental factors on crops traits of which only those that are genetic are heritable. Effective selection can be achieved through identification of the main genetic components and establishment of the degree of their effects on the expression of the traits. In the same vein, knowledge of factors that control inheritance of the traits is as important as the determination of the genetic parameters. Phenotypic and genotypic coefficients of variation (PCV and GCV) are used to determine the extent of variability among traits of crops and are essential in selecting polygenic yield determining traits [4]. Therefore, estimation of the genetic parameters such as variance, genetic coefficients of variation and heritability of the traits and the association of a particular trait in relation to others contributing to the yield of the crop would be of great importance in a successful breeding programme [5,6].

Genotypic correlation coefficient measures the genetic associations among traits and may provide important guide in a selection procedure. It shows the extent and direction of associations among the traits and relates responses of the crop to selection [7]. The magnitude of the genotypic and phenotypic correlations and their utilization in the selection procedures in stress or optimal environmental conditions had been specified by numerous scientists, for instance [8, 9,10] for maize, [11] for wheat, [12] for barley and [13] for *Vernomia*. Moreover, heritability provides information on the percentage of phenotypic variation in a population that is attributable to genetic variation. It is effective in selection progress for phenotypic performance because it predicts the importance of crop traits in selection [14]. The GCV along with heritability provides reliable estimates of the amount of progress that can be expected through phenotypic selection [15].

Nitrogen stress tolerant maize were bred because it has been established that lowering the N demand of a crop through breeding is the cheapest, most cost effective and sustainable option to increase grain yield of maize in poor fertility soil [16]. Then, needs to select most suitable hybrids among large number of newly bred hybrids arise. This could be effectively done through understanding and estimation of the genetic basis and relationship among the traits of the hybrids. Therefore, this study was conducted to estimate the genetic parameters for some traits of the white and yellow kernel single cross hybrid maize and to determine the genetic associations among the traits of the hybrid maize in contrasting soil N conditions. This information shall be useful for breeders in maize improvement programmes for tolerance soil nutrient utilization.

2. MATERIALS AND METHODS

2.1 Genotypes and Experimental Site

The test genotypes included 150 single cross white kernel hybrid maize with two check hybrids and 66 single cross yellow kernel hybrid maize with four check hybrids. The 150 white kernel hybrids were generated in crosses of the 20 white inbred lines of maize listed in Table 1 using North Carolina Design II. On the other hand, the 66 yellow kernel hybrids were developed in a half diallel mating design in all possible crosses involving yellow kernel maize inbred lines, also listed in Table 1. The hybrids generated were evaluated at the Institute of Agricultural Research and Training, Ibadan, Nigeria (3.56° E and 7.33° N 168 m asl). The check hybrids were obtained from International Institute of Tropical Agriculture. Annual mean amount of rainfall of the experimental site in 2014 and 2015 were 141.3 cm and 103.3 cm respectively while the temperature was 25.8°C in 2014 and 26.6°C in 2015.

2.2 Crop Cultivation and Management

The one hundred and fifty white kernel maize and 66 yellow kernel maize were evaluated with their respective checks in contrasting soil (stress and optimal) N conditions in Ibadan in 2014 and 2015. First evaluation was carried out from August to December of 2014 and second evaluation, from April to August 2015. The experiment for the white kernel maize was laid out in 19 × 8 lattice design while layout for the yellow kernel maize was 10 × 7 lattice design with three replicates for each maize set. Soil of the experimental field was depleted of its native N by continuously planting maize at a very high population density on the soil without application of fertilizer, uprooting and removing the biomass completely after each cropping. This depletion procedure was repeated until the soil N has been completely removed. Soil analysis was carried out to confirm the N status after each depleting process. The soil was depleted to zero level of N.

The plants were in two-row plots, 5 m long with a spacing of 0.75 m between rows and 0.5 m between plants in a row. Field was sown with three seeds and thinned to two plants per two weeks after planting (WAP) to achieve a plant population density of 53,333 plants ha^{-1}. The N concentrations applied were 30 and 90 kg N ha^{-1} denoting N stress and optimal N conditions, respectively. Fertilizer was applied in the form of N: P: K 15:15:15 at 30 kg ha^{-1} to each of N stress and optimal N plots at 2 WAP. The optimal N plots received 60 kg N ha^{-1} in the form of urea to bring the available N to 90 kg ha^{-1} two weeks later. All the plots received 60 kg P ha^{-1} as single super phosphate (P_2O_5) and 60 kg K ha^{-1} as muriate of potash (K_2O). Standard cultural practices were applied for field maintenance, harvesting and seed processing according to the recommendations of IAR&T [17].

2.3 Data Collection

Ten plants were randomly selected per plot for data collection. The data were collected on the maize plant as follows:

- Days to anthesis (DTA) counted as days from planting to the day 50% of the plants in a plot shed pollens.
- Days to silking (DTS) counted as days from planting to the day silk emerged in 50% of the plants in a plot.
- Anthesis-silking-interval (ASI) calculated as the difference between days to 50% silking and days to 50% anthesis.
- Plant height (PH) in cm was the height of the maize from ground level to the base of the tassel of the plant.
- Ear height (EH) in cm was the height of the maize from ground level to the base of uppermost ear of the plant.
- Leaf senescence (LS) were scored according to Bänziger et al. [18], three times at eight days apart during the latter part of grain filling on a scale from 0 to 10, dividing the percentage of estimated total leaf area that were dead by 10. Scale 1 = 10% of leaves are dead, 2 = 20%, 3 = 30%, 4 = 40%, 5 = 50%, 6 = 60%, 7 = 70%, 8 = 80%, 9 = 90% and 10 = 100% of the leaves were dead.
- Plant aspect (PASP) was visual assessment of quality scored on plot basis before harvest, after flowering (at brown silk stage) when plants were still green and ears fully developed on scale 1 to 5 where 1 = excellent; 5 = very poor. General appeal of the whole row plants, based on the relative plant and ear heights, uniformity of the plant stands, reaction of plants to diseases and insects as well as lodging were considered in the plant aspect scoring
- Ear aspect (EASP) was also visual assessment of quality scored on a scale of

1 to 5 where 1=excellent; 5=very poor. The score was taken on the pile of harvested ears of each plot when spread out and the general look of the ears was taken into account. Ear size, uniformity of colour and texture, grain fill, disease and insect damage were considered for this score.

- Grain yield (GY): All the maize plants were harvested when dry and shelled. The grain yield adjusted to 15% moisture content was estimated as:

$$GY\ (kg\ ha^{-1}) = \frac{GWT\ (kg)}{7.5\ m^2} \times \frac{(100-MC)}{(100-15\%)} \times 10{,}000\ m^2$$

Where GWT = Grain weight, MC = grain moisture content at harvest, moisture content = 15%, plot area = 7.5 m^2 and 1 ha = 10,000 m^2.

2.4 Data Analysis

Analysis of variance (ANOVA) was performed on the data collected using SAS [19] for each N condition across the two years separately for each maize types (white and yellow). Hybrids were considered fixed effects while replicates and year were considered as random effects. Phenotypic ($\delta^2 p$) and genotypic ($\delta^2 g$) variances were obtained for each N condition and maize type according to Baye [14] as:

$$\delta^2 g = MSp - \frac{MSe}{r}$$

$$\delta^2 p = \frac{MSg}{r} \text{ and } \delta^2 e = \frac{MSe}{r}$$

Where MS_p, MS_g, MS_e were mean squares of phenotype, genotype, and error, respectively; r was number of replication. Mean values of the traits were used to determine phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) according to Singh and Chaudhury [20] as:

$$PCV\ (\%) = \frac{\sqrt{\delta^2 p}}{x} \times 100;\ GCV\ (\%) = \frac{\sqrt{\delta^2 g}}{x} \times 100$$

Where: $\delta^2 g$ = genotypic variance, $\delta^2 p$ = phenotypic variance and x = sample mean. PCV and GCV values were categorized as low (0-10%), moderate (10-20%), and high at values greater than 20% according to Sivasubramanian and Menon [21]. Broad sense heritability (h^2) for specific traits was estimated according to the procedure of Falconer [22] as:

$$\text{Broad sense heritability } (h^2) = \frac{\delta^2 g}{\delta^2 p}$$

Where: $\delta^2 g$ = genotypic variance and $\delta^2 p$ = phenotypic variance. The heritability was rated low when the estimate was less than 40%; medium between 40 and 59%, high when between 60 and 79% and very high when greater than 80% [23].

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance of the Agronomic Traits of the Hybrid Maize in Contrasting Soil Nitrogen-Nutritional Conditions

The ANOVA of data pooled over the years for each N condition showed that significant variation due to genotypes (G) and years (Y) existed for grain yield and other traits of both types of maize evaluated with checks in both N stress and optimal N conditions (Table 2). Significant differences due to G × Y were also obtained for all the traits in N stress and optimal N conditions. Exception to these were the non-significant effect of environment for GY in white maize in N stress and non-significant effects of G × Y for ASI and PASP in both N stress and optimal N conditions, and EASP in N stress condition only in the white maize.

Phenotypic effect consists of the effects of genotypes and environments (years). Hence variation in the expression or performance of a crop is influenced by the environment Variation in the agronomic performance as well as the associations of the traits of the maize was due to the application of the genetic effects of the hybrids in varied N condition. The relatively lower GVs in relation to PVs for most the traits, especially GY, DTA, DTS, ASI, EASP and LS of both white and yellow maize in both N stress and optimal N conditions implies that genotypic effect was substantial on the traits. The effects were not, or minimally affected by the environment, so physical expression of the traits was mainly genetic. This is supported by the EVs for the traits which were lower than their respective GVs and PVs in the maize. That is, the genes expressed in each of the traits might be homozygous dominant since they were not influenced by environment. Vashistha et al. [24]

in their earlier study also observed low genetic variability for DTA and DTS as well as other traits in maize cultivars. This result further indicates the environment influence the expression of the traits in both N conditions.

Similarly, the lower GCVs than the PCVs for all of the traits shows limited extent of genetic divergence than morphology of the various traits. The GCV only cannot be used to determine the traits that are heritable. The environment might have played a significant role in the physical expression of the traits. The PCVs and GCVs of most of the traits of white maize were higher than yellow maize suggesting a greater variability among white maize than the yellow maize for the concern traits. Similarly, heritability estimates alone do not also provide adequate information on the resemblance of a variety in the next generation. Therefore, the CVs combined with heritability estimates to define the traits that are heritable and that can be used for selection in breeding programmes of the crop for N use in this study. Combination of CVs and heritability of traits are important guides to selecting polygenic yield determining traits [4].

Table 1. Description and sources of maize inbred lines and check hybrids obtained for the study

SN	Inbred	Pedigree	Source
		White kernel inbred lines	
1	TZEI1	TZE-W Pop STR C_0 S_6 Inbred 1-2-4	IITA
2	TZEI2	TZE-W Pop × 1368 STR S_7 Inbred 2	IITA
3	TZEI3	TZE-W Pop × 1368 STR S_7 Inbred 4	IITA
4	TZEI4	TZE-W Pop × 1368 STR S_7 Inbred 6	IITA
5	TZEI7	WEC STR S_7 Inbred 12	IITA
6	TZEI22	WEC STR S_7 Inbred 9	IITA
7	TZEI98	TZE-W Pop × LD S_6 Inbred 12-1-2	IITA
8	TZEI106	WEC STR S_8 Inbred 19A	IITA
9	TZEI188	TZE-W Pop STR C_0 S_6 Inbred 1-1-4	IITA
10	TZEI136	TZE-Y Pop STR C_0 S_6 Inbred 21-1-3	IITA
11	BD74-152	(DTPWC9-F67-2-2-1-B)-B	CIMMYT
12	BD74-147	(DTPWC9-F18-1-3-1-1-B)-B	CIMMYT
13	BD74-31	(CZL068)-B	CIMMYT
14	BD74-170	(LaPostaSeqC7-F103-2-2-2-1-B)-B	CIMMYT
15	BD74-128	([MBR-ET(W)C1F139-2-1-B-2-B-B-B-B-B-B×MBRC5BcF13-3-1-2-B-B-B-B-1-2-B-B-B×CML264Q]-1-1-B)-B	CIMMYT
16	BD74-171	(LaPostaSeqC7-F10-3-3-1-1-B)-B	CIMMYT
17	BD74-179	(LaPostaSeqC7-F71-1-2-1-1-B)-B	CIMMYT
18	BD74-175	(LaPostaSeqC7-F180-3-1-1-1-B)-B	CIMMYT
19	BD74-399	(LaPostaSeqC7-F64-2-6-2-2-B-B-B)-B	CIMMYT
20	BD74-55	(CML264)-B	CIMMYT
		Yellow kernel inbred lines	
1	TZEI8	TZE-Y Pop STR C_0 S_6 Inbred 62-3-3	IITA
2	TZEI10	TZE-Y Pop STR C_0 S_6 Inbred 152	IITA
3	TZEI11	TZE Comp5-Y C_6 S_6 Inbred 8	IITA
4	TZEI12	TZE Comp5-Y C_6 S_6 Inbred 8	IITA
5	TZEI13	TZE Comp5-Y C_6 S_6 Inbred 12	IITA
6	TZEI16	TZE Comp5-Y C6 S6 Inbred 31	IITA
7	TZEI124	TZE-Y Pop STR C_0 S_6 Inbred 3-1-3	IITA
8	TZEI128	TZE-Y Pop STR C_0 S_6 Inbred 10-4-4	IITA
9	TZEI146	TZE-Y Pop STR C_0 S_6 Inbred 90-1-3	IITA
10	BD74-165	(DTPYC9-F74-3-4-1-3-B)-B	CIMMYT
11	BD74-161	(DTPYC9-F46-3-9-1-1-B)-B	CIMMYT
12	BD74-222	(CLYN262)-B	CIMMYT

IITA, CIMMYT and KNC indicate International Institute of Tropical Agriculture, International Maize and Wheat Improvement Centre and kernel colour, respectively

3.2 Estimates of Variability and Heritability for the Traits of the Maize in Contrasting Soil Nitrogen-Nutritional Conditions

The GVs for all the traits of the white maize were lower than their PVs while EVs were lower than the PVs or GVs in N stress (Table 3). Similarly, the GCVs were lower than the corresponding PCVs for all the traits. The PCVs and GCVs for DTA and DTS were less than 10% while those of traits were higher. The PCV and GCV for the GY were about 20% and 19%, respectively. Heritability estimates for all the traits were high for ASI and PH and very high for GY, DTA, DTS, EH and LS in the N stress condition. The EVs were also lower than GVs which were in turn lower than the PVs for all the traits of the white maize in optimal N condition. The trend of the GCVs to PCVs were similar in the optimal N condition to that of the N stress condition. Heritability estimates of all the traits of the white maize were very high except PH which had high estimate.

The traits exhibited various level of heritability estimates. The estimates were ranged from moderate to very high for most of the traits, showing that inheritance of the traits is predictable. Therefore, all the traits are important for improvement of the crop. Heritability estimate is either high or very high in N stress for white maize while it was very high for most traits in optimal N condition. It ranged from medium to very high in N stress but was either high or very high in optimal N condition for yellow maize. This result suggests that inheritance of the traits can be predicted more for white maize than yellow maize, also in optimal N than stress condition. High heritability had been reported in maize especially for GY, PH and flowering traits [25,26].

The GCVs for DTA and DTS which were low and moderate for GY, PH, EH and LS of the white maize mean limited variation in expression of the traits in any of the two N conditions. Based on low GCVs with high heritability, any of GY, DTA, DTS, PH, EH and LS can therefore be reliably used as selection index in maize improvement for N utilization. Low environmental influence and high heritability estimates obtained for the DTA and DTS of the white maize suggests that additive genes action was responsible for inheritance of the traits in both N conditions. There is possibility of rapid progress in selection using these traits. Both additive and non-additive control the GY PH, EH and LS of the white maize due to moderate GCVs and high heritability. As a result of high GCV and heritability, ASI is more variable but could be easily heritable. Thus, it is governed by non-additive genes action.

Table 4 shows that the GVs were lower than the PVs for all the traits of the yellow maize in N stress condition. The EVs were also lower than the GVs for all the traits. The PCVs and GCVs were rated between low and moderate. The PCVs were low for DTA and DTS but moderate for GY, ASI, PH, EH and LS; while the GCVs were low for DTA, DTS, PH, and EH. Heritability estimates ranged from medium to very high in N stress condition. The estimates were medium for PH and EH; high for GY, ASI and LS while the DTS had very high heritability estimates. Similarly, in optimal N condition, the GVs were lower than the PVs for all the traits. The PCV ranged from low to high while the GCV ranged from low to moderate only. Environmental variances were lower than the GVs for all the-traits. Unlike in N stress condition, heritability estimates were from high to very high for the traits. They were high for DTA, ASI, PH and EH but very high for GY, DTS and LS in optimal condition.

For yellow maize, the low estimates of GCVs and high heritability for the DTA and DTS in N stress or optimal condition indicate tendency of the traits to reoccur in the same manner in future generations. This shows their inheritance are controlled by additive genes action. The GY, ASI, PH, EH and LS are governed by both additive and non-additive genes actions because they had moderate GCVs but high heritability in N stress condition. However, additive genes action is responsible for inheritance of PH and EH due to low GCVs and high heritability estimates in optimal condition. On the other hand, the GY, ASI and LS of the yellow maize had moderate GCVs and high heritability, thus both additive and non-additive actions govern inheritance of the traits in optimal condition. Aminu et al. [11] had earlier reported that low environmental effect with high heritability suggest additive genes action.

Nwangburuka and Denton [8] had also reported that traits that combines high genotypic coefficient of variation and high heritability are often controlled by additive genes action. The traits are suitable selection indices for yield in crop breeding programmes.

3.3 Inter-Relationship of the Agronomic Traits of the Hybrid Maize in Contrasting Soil Nitrogen-Nutritional Conditions

3.3.1 Correlations of traits of the white maize in contrasting soil nitrogen-nutritional conditions

Relationships among the traits of the white maize in N stress and optimal conditions were listed in Table 5. It was observed that the GY had positive and highly significant phenotypic and genotypic correlations with DTA, DTS and LS, but negative and significant correlations with PASP and EASP. The phenotypic, genotypic and environmental correlations of DTA with DTS were positive and highly significant. Similarly, the DTS and ASI positively correlated with one another, while DTA and DTS had negative and significant phenotypic and genotypic correlations with LS. The DTS had environmental correlations with ASI ($r=0.52^{**}$), PH ($r=0.52^{**}$) and EH ($r=-0.40^{**}$) and SG ($r=-0.35^{**}$). Table 4 also shows that phenotypic, genotypic and environmental correlations of PH with EH were highly positive and significant. The PH also showed phenotypic ($r=0.26^{**}$) and genotypic ($r=0.30^{**}$) correlations with SG, as well as phenotypic ($r=-0.20^{*}$) and genotypic ($r=-0.22^{*}$) correlations with PASP. The phenotypic and genotypic significant correlations between EH and LS as well as those of PASP and EASP were positive and significant in the N stress condition.

Inter-traits association is often expressed by phenotypic, genotypic and environmental correlations. Traits with positive and significant correlation coefficients with one another in any improvement program might simultaneously induce an increase in the other also, or vice versa. Therefore, understanding the inter-traits associations is essential for successful selection in breeding programme. Although phenotypic and genotypic correlations were of comparable magnitude, but the phenotypic correlation coefficients were in most cases lower than the genotypic correlation coefficients indicating that the traits were more related genotypically than phenotypically in the two types of maize. Consequently, environmental or non-additive effects were negligible while additive gene action effects dominate. Several authors among who were [27,28,8] had also explained that higher ratio of genotypic coefficients to phenotypic coefficients denotes that the traits are under the influence of genetic rather than environmental. Since environmental correlation coefficients were low for most traits in this study, phenotypic correlations which integrate the genotypic and environmental correlations would be good illustration of genotypic correlation coefficients.

On the other hand, the GY of the white maize had negative and significant phenotypic, genotypic and environmental relationships with PASP and EASP only in optimal N. There was no significant correlation among the GY and other traits. The DTA had high significant phenotypic ($r=0.96^{**}$), genotypic ($r=0.97^{**}$) and environmental ($r=0.92^{**}$) correlations with DTS, but significant phenotypic ($r=-0.27^{**}$) and genotypic ($r=-0.28^{**}$) correlations only with EH, while it had negative genotypic correlation with LS ($r=-0.20^{*}$) only. The DTS had positive and significant phenotypic, genotypic and environmental correlations ($p<0.01$) with ASI but the significance was negative with EH. The DTS had negative and significant environmental correlation with PH ($r=-0.20^{*}$) as well as negative and significant genotypic correlation with LS ($r=-0.20^{*}$). The PH had significant phenotypic, genotypic and environmental correlations with EH and EASP but phenotypic and genotypic significant correlations only ($p<0.1$) with PASP. The trend of correlation of PH with PASP and EASP was similar in both stress and optimal N conditions for the white maize.

3.3.2 Correlations of traits of the yellow maize in contrasting soil nitrogen-nutritional conditions

Analysis of the associations among the agronomic traits of the yellow maize indicated that the GY had positive and significant phenotypic and genotypic correlations with the PH, EH and LS but negative and significant phenotypic and genotypic correlations with DTA, DTS, ASI, PASP and EASP in N stress condition (Table 5). Only PASP and EASP had significant environmental associations with the GY. The DTA showed various levels of significant correlations with the DTS, ASI, PH, EH, LS and PASP. The correlation between DTA and DTS was high positive and significant ($p<0.01$) for the three genetic components. The DTS had positive and significant correlations with the ASI and PASP for the three components, but negative and significant correlations with the PH, EH and LS ($p<0.01$). The ASI had phenotypic ($r=-0.25^{*}$) and genotypic ($r=-0.32^{*}$) correlation with the EH only. However, EH had negative and significant phenotypic correlations with the PASP and EASP, negative and significant genotypic correlation with LS and EASP, but negative and significant environmental correlation with PASP. The LS had genotypic correlation with the PASP (r=0.32**) and EASP (r=0.49**) as well as phenotypic correlations with EASP (r=0.35**). There were also phenotypic (r=0.52**), genotypic (r=0.57**) and environmental (r=0.47**) correlations between PASP and EASP in the N stress condition.

Traits of both white maize and yellow maize evaluated exhibited various degrees of associations among the traits in both N conditions. The correlations ranged from non-significant to significant and negative to positive. Haq et al. [29,30,31] had reported differences in significant associations of among traits of maize in contrasting stress condition. Significant correlations have also observed among the grain yield and other agronomic traits of maize in optimum growing conditions [10,32,33,34]. The GY had moderately high phenotypic and genotypic coefficients with DTA, DTS, LS, PASP and EASP of the white maize in N stress condition. Selection for high grain yield can therefore be based on any of these traits and their phenotypic expression would be a good indicator of their genotypic potentiality. The ASI, PH and EH which recorded lower phenotypic and genotypic coefficients offered less scope for selection because they seemed to be much more under the influence of the environment. Positive association of GY with DTA, DTS and LS and its negative association with PASP and EASP of the white maize in N stress suggest that high yielding hybrids are late maturing with adequate leaf senescence ability. These attributes may be necessary to absorb and mobilize both the soil and solar nutrients for more GY than the early maturing maize that possess high leaf senescence attribute. This also confirms delayed flowering or low LS is effective in selection for high yielding white maize in the N stress condition. Such plants have the ability to stay green longer in the field and photosynthesize even with limited available N nutrients. On the other hand, the GY of the maize had negative relationships with PASP and EASP in optimal N. The GY may not necessarily have bright appearance. Thus, PH or EH may be considered when selecting for GY in optimal N condition in the white maize. Bello et al. [10] had proposed DTA, DTS, PH and EH as important selection criteria in improving hybrids for high GY while Bänziger et al. [18] suggested flowering traits and leaf senescence as low N tolerant traits.

The correlations among the traits of the yellow maize in optimal N were also reported in Table 6. The GY had significant phenotypic and genotypic correlations with PH, PASP and EASP but environmental correlations of these traits were not significant. The DTA had positive and significant phenotypic, genotypic and environmental correlations with the DTS and PASP while it had negative and significant correlation with PH. The DTA had phenotypic and genotypic correlations only with ASI and EH. The results also showed that the DTS had high phenotypic (r=0.62**), genotypic (r=0.71**) and highly moderate environmental (r=0.35**) correlations with ASI, and average phenotypic (r=-0.45**), genotypic (r=-0.49**) and environmental (r=-0.30*) correlations with the PH while the trait had only phenotypic (r=-0.49**) and genotypic (r=-0.60**) correlations with EH. The DTS also positively correlated with PASP in the optimal N condition. The ASI had negative and significant phenotypic and genotypic correlations with EH but positive and significant correlations with PASP and EASP. The correlations of PH were highly positive and significant (p<0.01) with EH but moderate and negative with PASP and EASP while the EH, PASP and EASP were negatively correlated. The phenotypic and genotypic correlations between the LS and EASP were positive and significant. Phenotypic, genotypic and environmental correlations between PASP and EASP were positive and highly significant in the optimal N condition.

Unlike in N stress condition, GY of the yellow maize had negative significant correlations with flowering traits. This indicates that GY of the yellow hybrids increased with reduced days to flowering. The hybrids may mature early and have high yield probably due to their ability to escape terminal moisture stress that may arise towards the grain filling stage of the crop. Positive and significant associations obtained between GY and PH of the maize in N stress implies that tall yellow maize generally excel in their capacity to support grain production by stem reserve mobilization. The PH may therefore be considered as a suitable trait for selection for GY of yellow maize in both N stress and optimal N conditions. Olakojo and Olaoye [32] reported this in their earlier study on maize. The significant association of GY with PASP and EASP of the maize in optimal N condition indicates that there is strong relationship between GY and the general appearance of the crop and the ears. These traits exhibited negative and significant environmental correlations with GY in optimal N meaning that the N deficiency may have severe effect on the PASP and EASP of yellow maize.

Table 2. Mean squares of some agronomic traits from the combined analyses of variance for the hybrid maize evaluated in contrasting N conditions in 2014 and 2015

Source of variation	df	Grain yield	Days to anthesis	Days to silking	Anthesis silking interval	Plant height	Ear height	Leaf senescence	Plant aspect	Ear aspect
White kernel maize in nitrogen stress condition										
Year	1	223057.0^{ns}	149.30***	159.17***	0.16*	2762.84***	202.97*	0.59*	3.69***	1.02*
Replicate (Year)	4	796049.7*	2.45**	2.80*	0.58^{ns}	3609.84***	299.37***	1.09***	1.52***	1.54***
Genotype	151	2824967***	5.83***	6.75***	1.42***	677.32***	280.10***	1.18***	0.45***	0.61***
Genotype × Year	151	1063090.6***	1.64***	1.96***	0.22^{ns}	200.09*	63.13***	0.39***	0.18^{ns}	0.23^{ns}
Error	496	284033.5	0.72	0.98	0.35	*113.42*	44.25	0.21	0.16	0.19
White kernel maize in optimal nitrogen condition										
Year	1	20518337.0***	284.08***	363.79***	4.92***	5805.37***	7716.39***	2.83***	0.05^{ns}	0.30^{ns}
Replicate (Year)	4	2243352.5**	1.81^{ns}	2.82*	0.37^{ns}	1174.12***	248.20***	1.25***	1.55***	0.66**
Genotype	151	4991746.6***	12.11***	13.21***	1.12***	821.26***	343.57***	1.17***	1.02***	1.03***
Genotype × Year	151	2045634.1***	3.11***	3.45***	0.22^{ns}	287.78***	112.04***	0.49***	0.19^{ns}	0.23***
Error	496	648034.0	0.88	1.03	0.26	153.40	57.85	0.19	0.18	0.16**
Yellow kernel maize in nitrogen stress condition										
Year	1	345177224.6***	246.87***	365.87***	11.67***	12424.96***	3030.56***	1.67*	14.67***	1.87**
Replicate (Year)	4	261855.4^{ns}	2.07^{ns}	1.71^{ns}	0.08^{ns}	1018.88*	468.03***	4.62***	0.37*	0.27^{ns}
Genotype	69	1047433.3***	6.36***	8.34***	0.88***	898.56***	178.10***	0.92***	0.30***	0.64***
Genotype × Year	69	1146459.1***	4.13***	5.35***	1.08***	509.15***	119.24**	0.55***	0.20*	0.48***
Error	240	360893.6	1.41	1.48	0.23	304.95	73.08	0.30	0.13	0.20
Yellow kernel maize in optimal nitrogen condition										
Year	1	230584526.8***	440.24***	749.34***	40.86***	67.28**	1531.82***	12.34***	19.29***	5.04***
Replicate (Year)	4	132352.8^{ns}	33.46***	39.43***	0.53^{ns}	1686.30***	631.53***	2.38***	1.03***	0.55^{ns}
Genotype	69	1899724.8***	5.90***	8.77***	1.21***	905.44***	222.77***	0.87***	0.32***	0.69***
Genotype × Year	69	1643032.5***	3.41***	5.23***	0.70***	467.45***	115.09*	0.46***	0.25***	0.51***
Error	240	403898.9	1.62	1.88	0.38	247.71	81.26	0.22	0.13	0.24

df, ns, ***, **, * are degree of freedom, not significant, significant at $p<0.001$, 0.01, and 0.05, respectively

Table 3. Mean value, variance and heritability of some agronomic traits of the white kernel hybrid maize evaluated in contrasting N conditions across 2014 and 2015

Trait	Mean	Variance			Coefficient of variation		Heritability (%)
		Phenotypic	Genotypic	Environ-mental	Phenotypic (%)	Genotypic (%)	
Nitrogen stress condition							
GY	3635.34 kg ha^{-1}	544891.01	499137.74	45753.27	20.31	19.43	91.60
DTA	57.98 days	1.10	0.96	0.14	1.81	1.69	87.27
DTS	60.21 days	1.26	1.08	0.19	1.86	1.73	85.71
ASI	2.23 days	0.28	0.21	0.06	23.77	20.63	75.00
PH	113.41 cm	147.57	108.58	38.99	10.71	9.19	73.58
EH	44.25 cm	59.25	48.83	10.42	17.40	15.80	82.41
LS	3.40	0.22	0.18	0.04	13.82	12.35	81.82
Optimal nitrogen condition							
GY	4855.23 kg ha^{-1}	965285.58	862194.87	103090.71	20.24	19.12	89.32
DTA	57.58 days	2.32	2.16	0.17	2.64	2.55	93.10
DTS	59.41 days	2.51	2.31	0.20	2.66	2.56	92.03
ASI	1.83 days	0.21	0.17	0.04	25.14	22.40	80.95
PH	112.98 cm	168.43	131.53	36.91	11.49	10.15	78.09
EH	45.32 cm	70.09	55.99	14.10	18.47	16.50	79.88
LS	2.82	0.22	0.18	0.03	16.67	14.89	81.82

GY = Grain yield, DTA= days to anthesis, DTS=days to silking, ASI=anthesis-silking-interval, PH=plant height, EH=ear plant, LS=leaf senescence.
$^{*, **}$ indicate significant at p<0.05 and 0.01 respectively

Table 4. Mean squares, variance and heritability of agronomic traits of the yellow kernel hybrid maize evaluated in contrasting N conditions across 2014 and 2015

Trait	Mean	Variance			Coefficient of variation		Heritability (%)
		Phenotypic	Genotypic	Environ-mental	Phenotypic (%)	Genotypic (%)	
				Nitrogen stress condition			
GY	2361.98 kg ha^{-1}	197670.07	136792.50	60877.57	18.82	15.66	69.20
DTA	57.62 days	1.18	0.93	0.26	1.89	1.67	78.81
DTS	60.05 days	1.58	1.28	0.29	2.10	1.88	81.01
ASI	2.43 days	0.18	0.14	0.04	17.28	15.23	77.78
PH	113.94 cm	144.67	78.79	65.88	10.56	7.79	54.46
EH	48.60 cm	28.87	15.29	13.58	11.05	8.05	52.96
LS	3.32	0.17	0.11	0.06	12.35	9.94	64.71
				Optimal nitrogen condition			
GY	4130.00 kg ha^{-1}	357745.84	291992.55	65753.29	14.48	13.08	81.62
DTA	56.90 days	1.12	0.85	0.27	1.86	1.62	75.89
DTS	54.05 days	1.62	1.32	0.30	2.35	2.13	81.48
ASI	2.15 days	0.20	0.14	0.06	20.93	17.21	70.00
PH	116.23 cm	163.18	123.95	39.23	10.99	9.58	75.96
EH	49.52 cm	36.76	22.55	14.20	12.24	9.59	61.34
LS	3.38	0.16	0.13	0.03	11.83	10.65	81.25

GY = Grain yield, DTA= days to anthesis, DTS=days to silking, ASI=anthesis-silking-interval, PH=plant height, EH=ear plant, LS=leaf senescence.

**, ** indicate significant at p<0.05 and 0.01 respectively*

Table 5. Correlation coefficients of agronomic traits of the white kernel hybrid maize evaluated in contrasting N conditions (N stress above diagonal; optimal N below diagonal) in 2014 and 2015

Trait	Parameter	GY	DTA	DTS	ASI	PH	EH	LS	PASP	EASP
GY	Phenotypic		0.34**	0.28**	-0.08	0.01	0.00	0.23**	-0.28**	-0.24*
	Genotypic		0.38**	0.32**	-0.08	-0.01	-0.02	0.27**	-0.32**	-0.27**
	Environmental		-0.01	-0.07	-0.11	0.14	0.17	0.02	-0.17	-0.11
DTA	Phenotypic	0.10		0.98**	0.08	-0.13	-0.15	-0.36**	-0.10	-0.11
	Genotypic	0.12		1.00**	0.11	-0.08	-0.13	-0.43**	-0.16	-0.15
	Environmental	-0.13		0.83**	-0.10	-0.34**	-0.32**	0.00	0.10	0.02
DTS	Phenotypic	0.07	0.96**		0.56**	-0.16	-0.18	-0.49**	-0.05	-0.03
	Genotypic	0.09	0.97**		0.57**	-0.11	-0.15	-0.58**	-0.10	-0.05
	Environmental	-0.17	0.92**		0.52**	0.52**	-0.40**	-0.35**	-0.06	0.09
ASI	Phenotypic	-0.11	0.08	0.39**		-0.10	-0.08	-0.34**	0.09	0.15
	Genotypic	-0.11	0.11	0.41**		-0.07	-0.07	-0.41**	0.12	0.19
	Environmental	-0.11	-0.15	0.30**		-0.19	-0.12	-0.09	0.01	0.03
PH	Phenotypic	0.11	-0.17	-0.16	-0.01		0.82**	0.26**	-0.20*	0.05
	Genotypic	0.11	-0.17	-0.16	0.02		0.82**	0.30**	-0.22*	0.09
	Environmental	0.13	-0.16	-0.20*	-0.11		0.83**	0.13	-0.15	-0.05
EH	Phenotypic	0.12	-0.27**	-0.27**	-0.04	0.89**		0.34**	-0.16	-0.12
	Genotypic	0.13	-0.28**	-0.28**	-0.01	0.94**		0.39**	-0.19	-0.16
	Environmental	0.05	-0.18	-0.24**	-0.15	0.69**		0.17	-0.08	0.01
LS	Phenotypic	0.00	-0.19	-0.19	-0.01	0.11	0.10		0.05	-0.02
	Genotypic	0.01	-0.20*	-0.20*	-0.01	0.14	0.10		0.09	-0.05
	Environmental	-0.01	-0.12	-0.10	0.02	-0.01	0.08		-0.05	0.06
PASP	Phenotypic	-0.45**	-0.11	-0.13	-0.08	-0.31**	-0.29**	-0.03		0.35**
	Genotypic	-0.47**	-0.14	-0.16	-0.11	-0.34**	-0.32**	-0.03		0.49**
	Environmental	-0.26**	0.14	0.16	0.07	-0.18	-0.14	0.01		0.04
EASP	Phenotypic	-0.40**	-0.04	-0.03	0.02	-0.25*	-0.31**	0.09	0.55**	
	Genotypic	-0.44**	-0.05	-0.05	-0.01	-0.26**	-0.32**	0.12	0.59**	
	Environmental	-0.20*	0.10	0.15	0.12	-0.22*	-0.24*	-0.08	0.37**	

*GY = Grain yield, DTA= days to anthesis, DTS=days to silking, ASI=anthesis-silking-interval, PH=plant height, EH=ear plant, LS=leaf senescence, PASP=plant aspect and EASP=ear aspect. *, ** indicate significant at p<0.05 and 0.01 respectively*

Table 6. Correlation coefficients of agronomic traits of the yellow kernel hybrid maize evaluated in contrasting N conditions (N stress above diagonal; optimal N below diagonal) in 2014 and 2015

Trait	Parameter	GY	DTA	DTS	ASI	PH	EH	LS	PASP	EASP
GY	Phenotypic		-0.27*	-0.34**	-0.31**	0.46**	0.39**	0.27*	-0.34**	-0.69**
	Genotypic		-0.30*	-0.39**	-0.43**	0.64**	0.50**	0.35**	-0.42**	-0.86**
	Environmental		-0.20	-0.19	0.01	0.19	0.22	0.08	-0.24*	-0.31**
DTA	Phenotypic	-0.13		0.95**	0.23	-0.33**	-0.35**	-0.30*	0.33**	0.17
	Genotypic	-0.15		0.95**	0.31**	-0.31**	-0.38**	-0.33**	0.34**	0.21
	Environmental	-0.12		0.92**	-0.03	-0.40**	-0.33**	-0.24*	0.35**	0.06
DTS	Phenotypic	-0.17	0.94**		0.54**	-0.35**	-0.39**	-0.28*	0.35**	0.17
	Genotypic	-0.17	0.96**		0.59**	-0.34**	-0.42**	-0.29*	0.36**	0.19
	Environmental	-0.15	0.90**		0.35**	-0.42**	-0.37**	-0.26*	0.41**	0.12
ASI	Phenotypic	-0.17	0.32**	0.62**		-0.19	-0.25*	-0.04	0.20	0.07
	Genotypic	-0.23	0.47**	0.71**		-0.23	-0.32**	-0.02	0.21	0.03
	Environmental	0.00	-0.10	0.35**		-0.11	-0.14	-0.08	0.20	0.16
PH	Phenotypic	0.29*	-0.45**	-0.45**	-0.20		0.79**	-0.21	-0.46**	-0.46**
	Genotypic	0.31**	-0.52**	-0.49**	-0.22		0.77**	-0.52**	-0.50**	-0.68**
	Environmental	0.22	-0.26*	-0.30*	-0.13		0.82**	0.27*	-0.42**	-0.11
EH	Phenotypic	0.19	-0.48**	-0.49**	-0.26*	0.86**		-0.09	-0.35**	-0.43**
	Genotypic	0.21	-0.60**	-0.60**	-0.37**	0.89**		-0.29*	-0.23	-0.57**
	Environmental	0.14	-0.21	-0.23	-0.07	0.82**		0.21	-0.48**	-0.22
LS	Phenotypic	-0.12	-0.11	-0.09	0.02	-0.12	0.00		0.11	0.35**
	Genotypic	-0.16	-0.07	-0.06	-0.03	-0.17	-0.03		0.32**	0.49**
	Environmental	0.03	-0.29*	-0.19	0.17	0.07	0.08		-0.16	0.04
PASP	Phenotypic	-0.28*	0.25*	0.29*	0.24*	-0.38**	-0.42**	0.15		0.52**
	Genotypic	-0.30*	0.26*	0.31**	0.32**	-0.43**	-0.46**	0.19		0.57**
	Environmental	-0.22	0.24*	0.26*	0.09	-0.29*	-0.33**	0.06		0.47**
EASP	Phenotypic	-0.47**	0.12	0.19	0.25*	-0.46**	-0.33**	0.33**	0.48**	
	Genotypic	-0.55**	0.07	0.07	0.29*	-0.53**	-0.33**	0.40**	0.51**	
	Environmental	-0.22	0.25*	0.31**	0.15	-0.29*	-0.35**	0.15	0.41**	

*GY = Grain yield, DTA= days to anthesis, DTS=days to silking, ASI=anthesis-silking-interval, PH=plant height, EH=ear plant, LS=leaf senescence, PASP=plant aspect and EASP=ear aspect. *, ** indicate significant at $p<0.05$ and 0.01 respectively*

4. CONCLUSION

Expression of PH, EH, LS and PASP was genetic in white maize and yellow maize in both N conditions. There is greater variability among white maize than the yellow maize for the traits. Inheritance of the traits can be predicted more for white maize than yellow maize, also in optimal N than stress condition. Any of GY, DTA, DTS, PH, EH and LS can be reliably used as selection index in maize improvement for N utilization. Additive genes action was responsible for inheritance of DTA and DTS while both additive and non-additive control the GY, PH, EH and LS of the white maize in both N conditions but ASI is governed by non-additive genes action. For yellow maize, the DTA and DTS are controlled by additive genes action in both N conditions. The GY, ASI, PH, EH and LS were governed by both additive and non-additive genes actions in N stress condition. Additive genes action is responsible for inheritance of PH and EH while both additive and non-additive actions govern inheritance of GY, ASI and LS of the yellow maize in optimal condition.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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