

Genetic Analysis of Seed Size, Maturity Class and Seed Coat Colour in Tropical Maize Inbred Lines for Yield Improvement

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Maize has potential for contributing to food security, but several challenges confronting its production has resulted in low yield in sub-Saharan Africa. The role of seed parameters in maize breeding is vital, but there is dearth of information on genetic basis of seed-size, maturity class (MC), and seed coat colour (SCC). Hence, a study was carried out to investigate genetic analysis and relationship between these seed parameters with seed yield (SY). Twenty-four (24) maize inbreds, classified based on MC and SCC were grouped as small seed-size (SSS) (<25 g) and large seed-size (LSS) (≥ 25 g) based on 100-seed weight. The inbreds were evaluated in 2023 and 2024 planting seasons in the field. Data collected on agronomic traits were subjected to analysis of variance, correlation and genetic analyses. Results obtained revealed that inbreds had average SY of 451.31 kg.ha⁻¹. Late-maturing inbreds with LSS performed better than other maturity class for SY. Also, inbreds with white seed coat out-yielded yellow seed coat, though not significant. A significant and positive relationship existed between seeds-size and MC with SY. Magnitude of phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all parameters and moderate broad-sense heritability was obtained for SY in both seed-size (49.08%) and MC (50.88%). This study has provided information on how to optimize multiple traits for improved productivity. Therefore, inbred TZEE-W-POP-STR-C6 with white seed coat and LSS had the highest SY. Thus, it is a candidate for the development of high yielding and extra-early hybrids in improvement programs.

Keywords: maize lines, seed yield, seed size, maturity class, seed coat colour, correlation, heritability

1 Introduction

Maize is globally ranked the third most important cereal in the world after wheat and rice. It is the first in sub-Saharan Africa (SSA) with a population of above 80% relying on it for livelihood (ASARECA, 2014). It is also one of the major sources of food for human, livestock, and industrial raw materials (brewery, confectionery) (Olakojo, 2001). The world maize acreage is about 201.09 million hectares with corresponding maize seed production of 1.16 billion tons and mean yield of 5.77 t.ha⁻¹ (USDA, 2024). However, the production share of Africa was about 67.69 million tons with an average seed yield of 3.1 t.ha⁻¹, obtained from 23.45 million hectares of land (USDA, 2024). Thus, the portion of Africa accounted for about 5.83% and 11.66% of the world maize production and acreage, respectively.

The low yield recorded in Africa has been attributed to many factors including poor soil fertility and high cost of fertilizer, poor investment in research and development (Badu-Apraku & Fakorede, 2017), the use of inappropriate varieties, poor agronomic practices (Badu-Apraku et al., 2014a), insurgence of pests and diseases (Badu-Apraku et al., 2014b). Other identified reasons for low yield include indiscriminate planting of maize cultivars without considering maturity class in the face of erratic rainfall patterns caused by climate change (Bello et al., 2012; Badu-Apraku et al., 2017), the use of maize seed with different sizes, which vary with location (Chaudhry & Ulah, 2001), and the breeding of maize with seed coat colour not favoured by farmers, though preferences vary across regions (Groote & Kimenju, 2008). Attention is gradually shifting to the development of improved

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high-yielding maize varieties or hybrids with large seed size, early maturity and cultivars with preferred seed coat colour.

Estimation of genetic parameters for yield and yield components provides understanding into the genetic control of seed size, maturity class, and seed coat colour and their likelihood for improvement through selection. Information on genetic parameters is assessed in any population based on genotypic and phenotypic coefficient of variation (GCV and PCV) (Onyia et al., 2017). The GCV is otherwise called genetic or breeding value, which is the heritable portion of the phenotype, whereas PCV combines genetic and environmental factors of which only those that are genetic are heritable (Triveni et al., 2014). Traits with high heritability are predominantly governed by additive gene action, which implies selection in early generations can lead to significant genetic gain (Falconer & Mackay, 1996). Estimating the genetic advance will help breeders to prioritize traits for selection in breeding programs, maximizing yield potential in tropical environments (Hallauer et al., 2010), therefore, breeding programs in tropical maize need to adopt an integrated approach, considering not only yield, but also the combined effects of seed size, maturity class, and seed coat colour to facilitate the development of maize varieties that will be well-adapted to specific tropical environments and meet diverse needs of farmers and consumers.

In spite of critical role of seed traits in maize breeding, there is little research that has comprehensively examined the genetic basis of seed size, maturity class, and seed coat colour in tropical maize inbred lines. This gap in knowledge limits the ability of breeders to effectively select for multiple desirable traits simultaneously, especially in tropical environments where maize faces unique abiotic and biotic stresses. Therefore, investigating the genetic relationships among these traits will provide breeders with crucial information on how to optimize multiple traits simultaneously for improved productivity and adaptability. This study therefore aimed at:

- a) investigating the effects of seed size, maturity class, and seed coat colour on seed yield in maize inbred lines;
- b) assessing the correlation between these parameters with seed yield;
- c) estimating the genetic components for seed yield and its components to assess their potential for genetic improvement.

2 Materials and Methods

2.1 Experimental Location and Genetic Materials

The experiment was carried out at the experimental field of the Institute of Agricultural Research and Training, Ibadan, Nigeria located in Rainforest-Savanna transition, with latitude 7.38' N, longitude 3.84' E, and altitude 160 m above sea level in 2023 and 2024 cropping season. The dominant soil type at the experimental site was classified as Ferric Lixisols. Experimental field over the years received annual mean rainfall of around 150 mm (Akinyosoye, 2022). Twenty-four (24) maize inbred lines, grouped into two seed sizes: small (<25 g) and large (≥ 25 g) based on their 100-seed weight (Akinyosoye et al., 2015) were used as genetic materials for this experiment (Table 1).

2.2 Experimental Design and Data Collection

Three maize seeds were sown per hole at 0.75 m between rows and 0.50 m within rows and later thinned to two plants per stand at two weeks after planting. The experiment was laid out in a randomized complete block design (RCBD) with three replicates, in a single row plot of 10 m length. Cultural practices such as weeding, fertilizer application, pest and disease control were carried out as at when due. Data were collected on agronomic traits described by Olakojo and Olaoye (2005) and Badu-Apraku et al. (2012).

2.3 Data Analyses

Analysis of variance (ANOVA) was performed on the collected data using SAS System for Windows 9.0 software. Correlation between yield and its components and between seed size, seed coat and maturity class with seed yield based on correlogram was carried out using Palaeontological Statistics (PAST, version 2.17) software package. Variances of Error (δ^2e), genotypic (δ^2g) and phenotypic (δ^2p) coefficient of variation were calculated from expected mean squares and were estimated (Hallauer and Miranda, 1988) as follows:

$$\text{environmental variance } (\delta^2e) = MSe \quad (1)$$

$$\text{genotypic variance } (\delta^2g) = \frac{(MSg - MSe)}{r} \quad (2)$$

where: MSg – mean square of genotype; MSe – mean square of error; r – number of replications

$$\text{phenotypic variance } (\delta^2p) = \delta^2g + \delta^2e = \text{eq. 2} + \text{eq. 1} \quad (3)$$

Table 1 Description of 24 maize inbred lines based on maturity class, seed coat colour and seed size

SN	Lines	Maturity class		Seed coat		Seed size				rank	Source
		days to maturity	rank	length (mm)	width (mm)	thickness (mm)	100-seed weight(g)				
1	1368	115–120	late	white	8.92	8.05	4.86	20.00	small	CIMMYT	
2	9450	115–120	late	yellow	7.64	7.89	6.01	20.00	small	CIMMYT	
3	KU1414-SR	115–120	late	yellow	9.04	7.96	5.42	21.70	small	IITA	
4	TZEE-W-POP-STR-C6	80–85	extra-early	white	10.29	8.39	4.65	25.00	large	IITA	
5	TZEEI 1	80–85	extra-early	white	9.43	7.92	4.86	15.00	small	IITA	
6	TZEEI 15	80–85	extra-early	white	10.88	7.74	4.30	18.33	small	IITA	
7	TZEEI 21	80–85	extra-early	white	10.50	7.81	5.35	23.30	small	IITA	
8	TZEEI 28	80–85	extra-early	white	10.02	8.43	5.87	25.00	large	IITA	
9	TZEEI 29	80–85	extra-early	white	9.13	7.76	5.07	25.00	large	IITA	
10	TZEEI 48	80–85	extra-early	white	8.35	8.66	5.51	15.00	small	IITA	
11	TZEEI 6	80–85	extra-early	white	8.18	7.71	5.33	20.00	small	IITA	
12	TZEI 122	90–95	early	yellow	6.33	7.75	6.33	18.33	small	IITA	
13	TZEI 129	90–95	early	yellow	8.50	9.22	6.91	30.00	large	IITA	
14	TZEI 135	90–95	early	yellow	8.79	7.14	4.03	18.33	small	IITA	
15	TZEI 144	90–95	early	white	8.51	8.94	4.28	15.00	small	IITA	
16	TZEI 158	90–95	early	yellow	7.83	7.64	4.57	15.00	small	IITA	
17	TZEI 16	90–95	early	yellow	7.59	6.97	5.09	15.00	small	IITA	
18	TZEI 161	90–95	early	yellow	7.71	7.76	6.13	20.00	small	IITA	
19	TZEI 17	90–95	early	yellow	9.41	7.77	3.79	18.33	small	IITA	
20	TZEI 178	90–95	early	yellow	8.61	8.17	4.97	20.00	small	IITA	
21	TZEI 31	90–95	early	yellow	7.71	7.81	5.77	15.00	small	IITA	
22	TZEI 60	90–95	early	white	7.52	9.04	5.83	20.00	small	IITA	
23	TZEI 7	90–95	early	white	10.19	8.16	4.85	20.00	small	IITA	
24	TZEI 8	90–95	early	yellow	8.11	8.03	5.96	21.67	small	IITA	

CIMMYT (Mexico) – International Maize and Wheat Improvement Center, IITA (Nigeria) – International Institute of Tropical Agriculture

Genotypic coefficient of variation (GCV):

$$GCV = \frac{(\sqrt{\delta^2 g})}{\bar{x}} \times 100 = \left[\frac{(\sqrt{\text{eq. 2}})}{\bar{x}} \right] \times 100 \quad (4)$$

Phenotypic coefficient of variation (PCV):

$$PCV = \frac{(\sqrt{\delta^2 p})}{\bar{x}} \times 100 = \left[\frac{(\sqrt{\text{eq. 3}})}{\bar{x}} \right] \times 100 \quad (5)$$

where: \bar{x} = mean of the trait

GCV and PCV values were categorized as low when less than 10%, moderate (10–20%) and high, greater than 20% (Sivasubramanian and Madhavamenon, 1973).

Heritability in broad sense (H^2) was determined according to the procedure by Singh and Chaudhary (1985):

$$H^2 = \frac{\text{total genetic variance}}{\text{total phenotypic variance}} = \left[\frac{(\delta^2 g)}{(\delta^2 p)} \right] \times 100 = \left(\frac{\text{eq. 2}}{\text{eq. 3}} \right) \times 100 \quad (6)$$

The heritability was rated low (<40%); moderate (40–59%), high (60–79%) and very high (>80%) (Singh, 2001). Genetic advance (GA) and genetic advance as percent of mean (GAM) were estimated according to Johnson (1955) as:

$$GA = k \times \delta p \times H \quad (7)$$

where: δp – the phenotypic standard deviation of the character; k – the standardized selection differential at 5% selection intensity (2.063)

$$GAM = \frac{GA}{\bar{x}} \times 100 = \left(\frac{\text{eq. 7}}{\bar{x}} \right) \times 100 \quad (8)$$

GAM is rated high when it is above 20%, moderate (10–20%) and low when it is less than 10%.

3 Results and Discussion

3.1 Results

3.1.1 Performance of Maize Inbred Lines for Yield and Yield Components as Affected by Seed Size, Maturity Class and Seed Coat Colour

Substantial variability was recorded among the inbred lines as reflected by coefficients of variation (CV). The CV ranged from 6.60% for days to 50% anthesis (DTA) to 70.02% for seed yield (SY) (Table 2). The maize inbred lines evaluated in this study had overall average SY

of 451.31 kg.ha⁻¹. Genotypic variation was observed among the 24 inbred lines evaluated, with five lines TZEE-W-POP-STR-C6, 1368, TZEI 135, TZEI 17, and KU1414-SR rated as the top performers with SY of 1163.40 kg.ha⁻¹, 784.32 kg.ha⁻¹, 716.34 kg.ha⁻¹, 660.13 kg.ha⁻¹, and 640.52 kg.ha⁻¹, respectively. However, five inbreds lines TZEI 122, TZEI 178, TZEI 21, TZEI 8, and TZEI 161 had the lowest SY (<250 kg.ha⁻¹). Inbred line TZEE-W-POP-STR-C6 was the earliest to reach DTA and silking (DS) within 49 and 51 days after planting (DAP), respectively, while line 1368 was the latest (61 and 65 DAP), followed by KU1414-SR and 9450 with mean values of 59 and 62 DAP for DTA and DS, respectively. Line TZEI 135 was the tallest, with plant and ear heights (PH, EH) of 1.54 m and 0.65 m, respectively, whereas TZEI 31 was the shortest with PH and EH of 1.07 m and 0.53 m, respectively. Two inbred lines (TZEI 29 and TZEE-W-POP-STR-C6) showed tolerance to ear rot disease with each inbred line scoring below 1.0 (Table 2).

The results obtained on yield and yield components in maize lines based on seed size revealed that large seed sized (LSS) lines performed better than the small seed sized (SSS) inbred lines for most of the characters (Table 3). The LSS lines had higher SY (566.99 kg.ha⁻¹) than SSS lines (428.17 kg.ha⁻¹) and for other yield components such as PH, EH, ear length (EL), ear diameter (ED), number of kernel row/ear (NRPE), and number of kernels/row (NKPR). On the other hand, LSS reached DTA and DS earlier than the SSS lines (Table 3). The effect of maturity class on yield and yield components in maize lines showed that late maturing maize lines had highest SY (640.52 kg.ha⁻¹) followed by extra-early maturing lines (451.80 kg.ha⁻¹), whereas lowest SY (407.34 kg.ha⁻¹) was recorded in early maturing maize lines. Also, late maturing maize inbred lines exhibited best performance for some of the yield components such as PH (1.37 m), EH (0.56 m), EL (0.08 m), and NRPE (15), while extra-early maturing maize inbred lines had the broadest ED (0.03 m), and highest NKPR (12) (Table 4). The maize inbred lines with white seed coat had higher SY (479.63 kg.ha⁻¹) compared to yellow seed coat (422.99 kg.ha⁻¹). Similarly, white seed coat reached DTA and DS earlier than the yellow seed coat. The lines with white seed coat were taller (1.31 m) than the yellow seed coat (1.28 m), also had higher ED (0.03 m) and NKPR (11) than the yellow seed coat. There was variation between SY recorded in the two years (Table 5).

Table 2 Effect of genotypes on yield and yield components in maize inbred lines

Lines	SY	DTA	DAS	PH	EH	EL	ED	NRPE	NKPR	EAS	EROT
TZEE-W-POP-STR-C6	1,163.40	48.50	51.33	1.50	0.55	0.11	0.04	19.63	13.25	2.25	0.92
1368.00	784.32	61.50	64.50	1.39	0.59	0.08	0.03	15.30	10.25	3.25	2.08
TZEI 135	716.34	53.50	56.50	1.54	0.65	0.10	0.03	19.30	11.58	2.75	1.75
TZEI 17	660.13	51.83	54.83	1.22	0.64	0.10	0.03	20.97	10.92	3.08	1.75
KU1414-SR	640.52	58.67	61.67	1.39	0.54	0.10	0.03	15.97	11.58	2.92	1.75
TZEI 60	633.99	53.67	56.83	1.36	0.58	0.10	0.03	18.63	9.42	3.42	2.75
TZEI 16	520.26	53.67	56.00	1.22	0.56	0.09	0.03	14.97	11.92	3.08	1.58
9450.00	496.73	58.50	61.67	1.36	0.56	0.08	0.03	12.97	10.75	3.08	1.58
TZEEI 1	477.12	49.83	52.00	1.37	0.57	0.06	0.04	12.80	14.25	2.92	1.92
TZEI 7	464.05	53.33	56.17	1.23	0.47	0.07	0.03	11.47	10.08	3.25	2.25
TZEI 31	441.83	54.33	57.17	1.07	0.53	0.08	0.03	11.63	9.08	3.75	2.42
TZEEI 15	437.91	50.17	52.17	1.21	0.55	0.06	0.03	10.80	11.92	3.08	2.25
TZEI 158	431.37	54.67	57.50	1.18	0.63	0.07	0.03	13.13	11.25	3.42	1.75
TZEEI 29	418.30	49.00	51.33	1.33	0.43	0.10	0.03	18.63	12.75	1.75	0.75
TZEI 129	411.77	52.83	55.50	1.41	0.54	0.07	0.03	12.13	8.42	3.42	1.08
TZEEI 6	333.33	50.33	53.33	1.17	0.45	0.08	0.03	15.30	12.25	2.92	1.75
TZEEI 48	281.05	50.17	54.17	1.28	0.51	0.05	0.03	9.47	8.75	3.42	1.42
TZEEI 28	274.51	49.33	51.83	1.32	0.57	0.07	0.03	11.30	11.42	3.42	2.42
TZEI 144	258.82	55.17	58.33	1.30	0.52	0.09	0.03	18.63	10.58	2.92	1.08
TZEI 122	248.37	52.67	55.00	1.36	0.47	0.06	0.03	11.30	9.08	3.58	1.58
TZEI 178	231.37	51.50	53.50	1.13	0.42	0.06	0.03	15.22	7.92	2.92	1.58
TZEEI 21	228.76	49.67	51.50	1.24	0.51	0.07	0.03	13.13	11.58	2.92	1.75
TZEI 8	159.48	52.83	55.17	1.14	0.52	0.09	0.03	16.13	9.58	3.58	2.25
TZEI 161	117.65	53.17	57.33	1.31	0.57	0.07	0.03	11.47	9.92	3.25	1.08
Mean	451.31	52.87	55.64	1.29	0.54	0.08	0.03	14.60	10.77	3.10	1.73
%CV	70.04	6.60	7.05	9.94	13.1	25.21	18.71	29.79	20.55	20.6	48.22
P-value	**	**	**	**	**	**	**	**	**	**	**
Std error	26.34	0.29	0.32	0.01	0.01	0.002	0.001	0.36	0.18	0.05	0.07

* significant at $p = 0.05$, ** significant at $p = 0.01$, ns – non-significant $p = 0.05$; SY – seed yield ($\text{kg}\cdot\text{ha}^{-1}$); DTA – days to 50% anthesis; DAS – days to 50% silking; PH – plant height (m); EH – ear height (m); EL – ear length (m); ED – ear diameter (m); NRPE – number of kernel rows per ear; NKPR – number of kernels per row; EAS – ear aspect [1 (excellence ear) – 5 (very poor ear)]; EROT – ear rot [1 (excellence ear) – 5 (very poor ear)]

Table 3 Effect of seed size on yield and yield components in maize inbred lines

Traits	Seed.size	Min	Max	Mean	P value	Std error	CV (%)
Seed yield (kg.ha ⁻¹)	large	39.22	1,764.71	566.99a	*	85.85	74.18
	small	38.02	1,647.06	428.17b		26.24	67.13
Days to 50% anthesis	large	47.00	54.00	49.92b	**	0.41	4.04
	small	49.00	66.00	53.46a		0.31	6.40
Days to 50% silking	large	50.00	59.00	52.50b	**	0.43	4.05
	small	51.00	69.00	56.27a		0.35	6.93
Plant height (m)	large	1.27	1.53	1.38a.	**	0.02	5.73
	small	0.98	1.56	1.28b		0.01	10.03
Ear height (m)	large	0.33	0.60	0.52a	ns	0.01	12.97
	small	0.36	0.67	0.54a		0.01	13.03
Ear length (m)	large	0.05	0.13	0.08a	ns	0.002	25.39
	small	0.01	0.13	0.08a		0.001	25.07
Ear diameter (m)	large	0.02.	0.05	0.03a	ns	0.001	17.45
	small	0.01	0.04	0.03a		0.001	18.50
Number of kernel rows/ear	large	9.60	23.00	15.43a	ns	0.92	29.33
	small	1.40	24.50	14.43a		0.39	29.88
Number of kernels/row	large	6.50	15.00	11.46a	ns	0.44	18.90
	small	1.50	16.00	10.63a		0.20	20.74
Ear aspect (0–5)	large	1.50	4.00	2.71b	**	0.17	30.76
	small	0.50	4.50	3.17a		0.05	17.87
Ear rot (0–5)	large	0.50	4.00	1.29b	**	0.18	70.28
	small	0.50	4.00	1.82a		0.07	43.69

*significant at $p = 0.05$, **significant at $p = 0.01$; ns – non-significant $p > 0.05$; means with the same letter(s) in the same column or row are not significantly different from each other at $p = 0.05$

Table 4 Effect of maturity class on yield and yield components in maize inbred lines

Traits	Maturity	Min	Max	Mean	P-value	Std error	CV (%)
SY	early	39.22	1647.06	407.34b	*	32.33	70.11
	extra	78.43	1764.71	451.80b		50.73	77.80
	late	79.03	1176.47	640.52a		67.77	44.89
DTA	early	50.00	58.00	53.32b	**	0.19	3.30
	extra	47.00	53.00	49.62c		0.16	2.30
	late	56.00	66.00	59.56a		0.61	4.35
DAS	early	51.00	67.00	56.14b	**	0.29	4.61
	extra	50.00	58.00	52.21c		0.21	2.90
	late	59.00	69.00	62.61a		0.60	4.10
PH	early	0.98	1.56	1.27b	**	0.02	11.56
	extra	1.14	1.53	1.30b		0.01	7.89
	late	1.32	1.42	1.38a		0.01	2.54
EH	early	0.38	0.67	0.55ab	*	0.01	13.81
	extra	0.33	0.60	0.52b		0.01	12.32
	late	0.42	0.61	0.56a		0.01	8.70
EL	early	0.01	0.13	0.08ab	*	0.002	25.65
	extra	0.02	0.13	0.07b		0.003	28.79
	late	0.06	0.11	0.08a		0.002	14.73
ED	early	0.01	0.04	0.03b	**	0.001	19.51
	extra	0.02	0.05	0.03a		0.001	15.11
	late	0.02	0.04	0.03b		0.001	17.26
NRPE	early	1.40	24.50	15.00a	ns	0.51	30.06
	extra	5.10	23.00	13.88a		0.64	32.40
	late	10.60	20.00	14.74a		0.69	20.02
NKPR	early	1.50	15.00	9.98b	**	0.24	21.38
	extra	5.50	16.00	12.02a		0.28	16.54
	late	8.50	13.50	10.86b		0.36	14.10
EAS	early	0.50	4.50	3.26a	**	0.06	18.26
	extra	1.50	4.00	2.83b		0.10	25.05
	late	2.50	3.50	3.08ab		0.08	11.46
EROT	early	0.50	4.00	1.76a	ns	0.09	49.80
	extra	0.50	4.00	1.65a		0.12	54.41
	late	0.50	2.50	1.81a		0.12	28.71

* significant at $p = 0.05$, **significant at $p = 0.01$; ns – non-significant $p > 0.05$; mteans with the same letter(s) in the same column or row are not significantly different from each other at $p = 0.05$

Table 5 Effect of seed coat colour on yield and yield components in tropical maize inbred lines

Traits	Seed Coat	Min	Max	Mean	P value	Std error	CV (%)
Seed yield (kg.ha ⁻¹)	white	78.43	1764.71	479.63a	ns	38.42	67.97
	yellow	39.22	1647.06	422.99a		36.00	72.22
Days to 50% anthesis	white	47.00	66.00	51.72b	**	0.45	7.53
	yellow	50.00	61.00	54.01a		0.30	4.77
Days to 50% silking	white	50.00	69.00	54.46b	**	0.50	7.79
	yellow	52.00	67.00	56.82a		0.37	5.59
Plant height (m)	white	1.13	1.53	1.31a	ns	0.01	7.66
	yellow	0.99	1.56	1.28a		0.02	11.78
Ear height (m)	white	0.33	0.63	0.52b	*	0.01	11.97
	yellow	0.38	0.67	0.5527a		0.01	13.54
Ear length (m)	white	0.03	0.13	0.08b	ns	0.002	26.39
	yellow	0.01	0.13	0.08b		0.002	24.05
Ear diameter (m)	white	0.02	0.05	0.03a	**	0.001	13.72
	yellow	0.01	0.04	0.03b		0.001	20.92
Number of kernel rows/ear	white	5.10	24.50	14.59a	ns	0.51	29.92
	yellow	1.40	23.00	14.60a		0.51	29.86
Number of kernels/row	white	5.50	16.00	11.38a	**	0.23	17.60
	yellow	1.50	15.00	10.17b		0.26	22.24
Ear aspect (0–5)	white	1.50	4.50	2.96b	*	0.08	23.00
	yellow	0.50	4.50	3.24a		0.06	17.58
Ear rot (0–5)	white	0.50	4.00	1.78a	ns	0.11	52.75
	yellow	0.50	4.00	1.68a		0.08	42.75

* significant at $p = 0.05$, **significant at $p = 0.01$; ns – non-significant $p > 0.05$; means with the same letter(s) in the same column or row are not significantly different from each other at $p = 0.05$

3.1.2 Correlation Matrix for Yield and Yield Components of Maize Inbred Lines

Correlation between yield and its components in maize inbred lines based on correlogram are presented in Fig. 1. Thus, blue and red circles indicate positive and negative correlations, respectively. White boxes connote non-significant correlations, whereas ash boxes indicate significant associations between the traits. In addition, the colour intensity and circle size are proportional to the correlation coefficients. The legend colour on the right side of the correlogram displays the correlation coefficients and their corresponding colours. It was observed that highly significant and positive relationship existed between SY and most of its components such as SY with PH (0.37**), EH (0.33**), EL (0.46**), ED (0.30**), NRPE (0.39**), NKPR (0.24**), but significant and negative relationship was recorded between SY and ear aspect. Furthermore, it was observed that significant and positive relationship existed between seeds size and SY ($r = 0.16^*$), whereas non-significant and negative relationship was observed between seed coat colour and S ($r = -0.19$). Also, a highly significant and positive

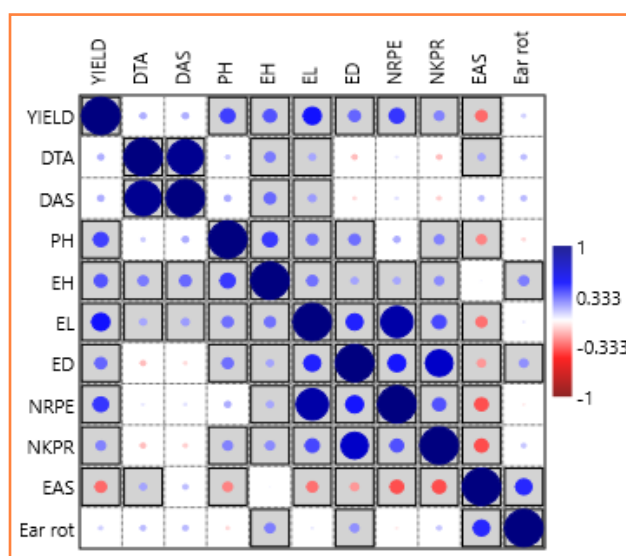


Figure 1 Correlogram for yield and its components of maize inbred lines evaluated

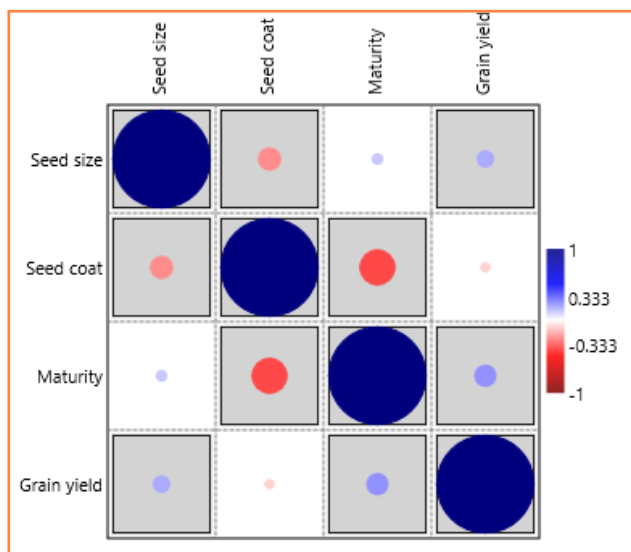


Figure 2 Correlogram between seed size, seed coat and maturity class with seed yield in maize inbred lines evaluated at $p < 0.05$ level of significance

relationship existed between maturity class and SY ($r = 0.21^{**}$). On the other hand, association among the three factors revealed that seed size was negatively and highly significantly correlated with seed coat colour ($r = -0.22^{**}$), but seed size was positively related with maturity class ($r = 0.10$). Significant and negative relationship was found between maturity class and seed coat colour ($r = -0.36^{**}$) (Fig. 2).

3.1.3 Estimates of Genetic Parameters of Inbred Lines for Yield and Yield Components as Affected by Seed Size, Maturity Class, Seed Coat Colour

Phenotypic coefficients of variation (PCV) varied between 12.11% (PH) in seed coat to 98.37% (SY) in maturity class, while genotypic coefficients of variation (GCV) ranged from 2.40% for NRPE in maturity class to 73.59% for ear rot in seed size. Across genotypes, PCV ranged from 9.01% for DTA to 85.04% for SY. The GCV had a range of 8.52% for DTA to 66.67% for SY. It could be affirmed that the magnitude of PCV for SY and its components was greater than GCV (Table 6). Heritability estimates in a broad sense revealed ranged from 4.58% (low) in seed coat colour, followed by 49.08% (moderate) in seed size to 50.88% (moderate) in maturity class for SY, while most of the traits measured had high heritability values ($\geq 50\%$). Across genotypes, SY had high heritability (61.45%), and all of the traits exhibited moderate to very high heritability. Genetic advance of the mean (GAM) showed that SY and most of the traits had high GAM ($>20\%$) based on seed size, maturity class, seed coat colour, and across (Table 6).

3.2 Discussion

High genetic variability recorded for seed yield (SY) of the inbred lines evaluated as reflected by coefficient of variation (CV) with CV of 70.11% suggests significant genetic variability among the inbred lines. This variability is beneficial in breeding programs, as it provides a wider pool of genetic resources that can be exploited for improvement. High genetic variation implies that the lines have potential for yield improvement, making it possible to select superior lines for breeding programs. This variability aligns with previous reports on maize (Bello et al., 2012) and suggests that there is ample opportunity for further genetic improvement of yield through selection or hybridization. However, the low CV ($<8\%$) for 50% days to anthesis (DTA) and silking (DAS) indicates low genetic variability and high genotypic uniformity for both traits. This suggests that the inbred lines are consistent in their flowering time, which can be an advantage for breeding programs targeting uniform crop maturity, especially in the development of maize hybrids.

The large seed size performed better than the small seed size of maize lines for SY and most of the yield components in this study suggest that seed size could be genetically linked to other desirable traits, such as better nutrient reserves for early seedling vigour, rapid development, and improved yield. It has been reported that larger seeds generally have more stored energy in the form of carbohydrates, proteins, and lipids, which can contribute to stronger and more vigorous seedlings (Mandal et al., 2008; Wen et al., 2018). For instance, Akinyosoye et al. (2015) conducted a groundbreaking research on the effect of maize seed size on *in-vitro* seed germination, seedling growth, embryogenic callus induction, and plantlet regeneration using biotechnological approach. The results obtained from their study indicated that larger seeds produced seedlings with better growth characteristics and higher potential for embryogenic callus induction and subsequent plantlet regeneration. This could help in developing high-yielding maize hybrids with larger seed size in maize improvement programs. Also, Kara (2011) investigated the effect of seed size and shape on maize's seed yield and yield components. The study found that large seeds performed better than small seeds in some important yield components, while seed shape had no significant effect. The results obtained from this study is also corroborated by the reports of others in different crops (Royo et al., 2006; Kara, 2011). In addition, it was observed that inbred lines with large seed size (LSS) reached DTA and DS earlier than the small seed size (SSS), which could be due to the greater initial energy reserves in large seeds, allowing seedlings to grow more rapidly

Table 6 Estimates of genetic parameters of inbred lines as affected by seed size, maturity class, seed coat colour and across genotypes

Estimates	SY	DTA	DAS	PH	EH	EL	ED	NRPE	NKPR	EAS	EROT	
												Seed size
Genotypic variance	9,5462.34	80.09	90.05	854.90	9.42	1.30	0.72	0.25	2.91	1.32	1.62	
Phenotypic variance	19,4514.75	90.69	103.65	1003.09	58.38	5.30	1.06	19.32	7.79	1.71	2.27	
Genotypic coefficient of variation (%)	68.46	16.93	17.06	22.63	5.70	14.40	26.85	3.45	15.83	37.10	73.59	
Phenotypic coefficient of variation (%)	97.72	18.01	18.30	24.51	14.19	29.10	32.53	30.11	25.92	42.17	87.10	
Broad sense heritability (%)	49.08	88.31	86.88	85.23	16.14	24.48	68.11	1.31	37.31	77.41	71.37	
Genetic advance of mean (%)	98.94	32.82	32.80	43.10	4.72	14.69	45.71	0.81	19.95	67.35	128.25	
Maturity class												
Genotypic variance	100,267.43	219.99	241.52	263.07	46.38	2.90	0.91	-0.12	19.26	0.79	0.14	
Phenotypic variance	197,084.26	222.93	246.75	418.25	93.58	6.80	1.22	18.96	23.39	1.17	0.55	
Genotypic coefficient of variation (%)	70.16	28.05	27.93	12.55	12.65	21.52	30.18	2.40	40.75	28.61	21.96	
Phenotypic coefficient of variation (%)	98.37	28.24	28.23	15.83	17.96	32.97	35.00	29.82	44.90	34.84	42.93	
Broad sense heritability (%)	50.88	98.68	97.88	62.90	49.57	42.59	74.33	0.65	82.35	67.43	26.16	
Genetic advance of mean (%)	103.24	57.49	57.01	20.54	18.37	28.97	53.67	0.40	76.29	48.47	23.17	
Seed coat colour												
Genotypic variance	4,843.55	59.34	62.17	80.23	81.47	0.20	2.58	-6.40	15.99	0.79	0.12	
Phenotypic variance	105,824.02	70.38	76.36	244.90	128.90	4.22	2.87	12.81	20.59	1.19	0.57	
Genotypic coefficient of variation (%)	15.42	14.57	14.17	6.93	16.76	5.66	50.79	17.33	37.13	28.69	19.80	
Phenotypic coefficient of variation (%)	72.08	15.87	15.71	12.11	21.08	25.97	53.65	24.51	42.13	35.16	43.82	
Broad sense heritability (%)	4.58	84.31	81.41	32.76	63.20	4.75	89.63	49.99	77.66	66.56	20.42	
Genetic advance of mean (%)	6.81	27.60	26.38	8.19	27.49	2.55	99.20	25.28	67.49	48.28	18.46	
Across												
Genotypic variance	90,529.28	20.30	22.61	253.79	68.17	4.23	0.22	18.36	4.04	0.30	0.35	
Phenotypic variance	147,311.24	22.67	27.06	295.97	83.97	6.19	0.47	28.45	7.01	0.54	0.87	
Genotypic coefficient of variation (%)	66.67	8.52	8.55	12.33	15.33	25.99	14.84	29.35	18.66	17.57	34.20	
Phenotypic coefficient of variation (%)	85.04	9.01	9.35	13.31	17.02	31.45	21.70	36.53	24.58	23.63	53.92	
Broad sense heritability (%)	61.45	89.54	83.55	85.75	81.18	68.32	46.81	64.53	57.63	55.28	40.23	
Genetic advance of mean (%)	107.82	16.63	16.11	23.55	28.50	44.32	20.95	48.63	29.23	26.95	44.75	

and reach important developmental stages faster. This assertion is corroborated by the findings of Mandal et al. (2008) who reported that large seeds generate more sugar monomers due to elevated amylase activity, which catalyzes the breakdown of starch into sugars. These sugars, in turn, support respiration in the embryo, promoting early developmental processes in *Hyptis suaveolens* (Lamiaceae). Thus, Breeders can leverage this to develop early-maturing maize varieties or hybrids with large seed sizes that adaptable to various agroecological zones or cropping systems.

The late-maturing maize inbred lines had highest seed yield and better performance for most of the other yield components compared to other maturity classes. This might be due to greater biomass accumulation, and better efficient use of resources than the rest during vegetative and reproductive stages. Thus, better yield potential for late maturing maize lines make them more suitable for environments with longer cropping seasons and favourable conditions, while early and extra-early lines are better suited for regions with shorter cropping seasons or environments prone to drought or early rainfall cessation, allowing crops to mature before emergence of adverse weather conditions (Olakojo & Olaoye, 2005; Bello et al., 2012; Akinyosoye, 2022). It is well established that late maturing genotypes achieve higher yields due to their extended duration for metabolic processes, contributing to both seed and stover production (Hussain et al., 2011). In contrast, early-maturing genotypes require fewer maize heat units to reach flowering, whereas late-maturing genotypes have a prolonged vegetative phase. As a result, early-flowering maize plants tend to exhibit lower seed yield compared to late-maturing genotypes (Khan et al., 2011).

The maize inbred lines with white seed coat had higher SY than yellow seed coat, although not statistically significant in this study. It has been reported that yellow maize naturally contains carotenoid pigments such as beta-carotene, lutein, and zeaxanthin in its endosperm, which contribute to its colour (Muzhingi et al., 2008). The biosynthesis of carotenoids in yellow maize requires energy and resources that could otherwise be channelled towards plant growth and development than seed production. The diversion of metabolic energy towards pigment production may contribute to low yield. Previous reports indicated that coat colour is a polygenic trait controlled by multiple genes across various plant species (Egbadzor et al., 2014). The genes controlling carotenoid production in the endosperm of yellow maize might be linked to other genes that negatively impact yield. A study was conducted on biofortified yellow or orange maize varieties and conventional white maize in Malawi under the AFIKEPO Nutrition Program, the results

obtained revealed that farmers harvested more bags of maize ears from conventional white maize than in biofortified orange maize per hectare. Despite higher resistance potential of biofortified yellow or orange maize varieties to storage pests like weevils, biofortified maize was reluctantly adopted by the farmers due to its low yield compared to white maize (Nkhata et al., 2024). This scenario may occur due to giving more priority to improving nutritional quality over yield in some cases in breeding programs. Therefore, breeding efforts should be geared towards improving biofortified yellow maize for higher yield to foster food security.

The significant and positive correlation between SY and most of its yield components, suggests that that these traits could be governed by similar genes with pleiotropic effect or closely linked genes (Brown & Caligari, 2008). As a result, these traits could contribute directly or indirectly to yield improvement, indicating that improvements in one trait can positively influence yield. Correlation between seed size, seed coat, and maturity class with SY in maize lines in this study showed that a significant and positive relationship existed between seed size and SY. This suggests that, as the size of the seeds increases, the SY also tends to increase. However, it is important to consider other factors such as soil fertility, weather conditions, and crop management practices to maximize yield potential. Positive correlation between seed size and SY had been previously reported on different crops (Mandal et al., 2008; Kara, 2011). A highly significant and positive correlation between maturity class and SY in maize suggests that maize lines evaluated in this study tend to exhibit corresponding trends in yield in their maturity class (extra-early, early, and late). This positive relationship implies that selecting maize lines based on the appropriate maturity class can improve SY performance under different environmental conditions. Positive association between maturity class and SY had been previously reported on maize (Hussain et al., 2011). A non-significant and negative relationship between seed coat colour and SY in maize indicates that variations in seed coat colour affected SY. The report obtained in this study is in line with the findings of Halilu et al. (2016) who reported non-significant and negative relationship between SY and α -carotene in yellow maize.

The estimates of genetic parameters revealed that PCV was higher than GCV for SY and its components in seed size, maturity class, seed coat colour, and across lines evaluated in this study, but high percent GCV to the PCV is desirable due to the fact that GCV represents only the genetic variability, while PCV accounts for both genetic and environmental variability. This suggests the dominance of environments in the expression of all of the traits studied among the lines. Similar results had also

been reported by others (Bello et al., 2012; Ogunniyan & Olakojo, 2015). Singh and Narayanan (1993) had earlier reported that high values of GAM are indicative of additive gene action whereas low values are indicative of non-additive gene action. The implication of moderate heritability recorded for SY in seed size and maturity class is that the trait is moderately influenced by both genetic and environmental factors. It had been reported that the high GAM coupled with high heritability estimates offers the most suitable condition for selection. It also indicates the presence of additive genes in the trait and further suggests reliable crop improvement through selection of such traits (Nwangburuka & Denton, 2012; Ogunniyan & Olakojo, 2015). Although the heritability for SY related to seed coat color is low, the high GAM indicates that there may be phenotypic variation that can be exploited. This could imply that while genetic influence was low, the trait itself might still contribute to observable improvements in yield through specific breeding strategies.

4 Conclusion

Late-maturing inbreds with large seed sizes performed better than other maturity class for seed yield. Also, inbreds with white seed coat out-yielded yellow seed coat, though not significant. A significant and positive relationship existed between pair of seeds-size and maturity class, whereas non-significant and negative relationship was observed between seed coat colour and seed yield. Magnitude of phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all parameters and moderate broad-sense heritability was obtained for seed yield in both seed-size and maturity class. A very high genetic advance of mean was recorded for seed yield and other traits in all parameters. Therefore, this study has provided information on how to optimize multiple traits for improved productivity. Breeders might have some success by considering seed size and maturity class in breeding programs for developing high-yielding maize hybrids or varieties with desired maturity class, but other management practices are necessary to achieve consistent improvements.

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