Journal of Agricultural Sciences (Belgrade) https://doi.org/10.2298/JAS2102105O
Vol. 66, No. 2, 2021 UDC: 633.15:631.527.5(669)
Pages 105-119 Original scientific paper

THE VARIABILITY OF GRAIN YIELD, SEED MORPHOMETRIC AND VIGOUR TRAITS OF EARLY MATURING HYBRID MAIZE

Dotun J. Ogunniyan[1*], Johnson A. Adetumbi[1], Julius O. Olasoji[1] and Solomon A. Makinde[2]

[1]Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria
[2]Department of Plant Breeding and Seed Technology, Federal University of Agriculture, Abeokuta

Abstract: Breeding for yield and quality requires the assessment of the seed metrics and vigour traits. This study, therefore, assessed the variability and interdependence of grain yield (GY), seed morphometric and vigour traits in hybrid maize. Seeds of 75 early maturing hybrid maize varieties were evaluated for morphometric traits and quality in four replicates. A field trial laid out in a randomised complete block design with three replicates was also conducted in Ibadan, Nigeria, to determine the grain yield of the hybrids. Data collected on the GY, seed dimension and quality were subjected to analysis of variance. The least significant difference was used to separate means. Relationships among the GY, seed morphometric and vigour traits were determined using correlation coefficients, while principal component (PC) analysis was performed for variability among the hybrids. Significant differences (*P<0.001*) were found in the GY, seed dimension and vigour traits. Four of the nine highest yielding hybrids had ECT higher than 30.0 μsg^{-1} cm^{-1}. The GY correlated with seed diameter (SDT) (0.40^{**}), seed width (SWD) (0.36^{**}), seed length (SLG) (0.35^{**}), seed area (SAR) (0.30^{**}) and seed vigour (SVI) (0.30^{**}). The SAG correlated with SDT, SLG, seed thickness (STH) and SAR. All the seed vigour traits correlated with one another. The PC I explained GY, SDT, SWD, SLG, SAR and SVI, indicating their importance in GY improvement. Seed angle, length and diameter were versatile in maize varietal selection. Identified high yielding hybrids with seed morphometric and vigour qualities can be explored by seed companies as innovation in the seed production business.

Key words: eigenvalues, electrical conductivity, maize yield, seed metrics, seed vigour.

*Corresponding author: e-mail: dotunogunniyan@yahoo.com

Introduction

Maize is among the few staple crops grown in almost all the sub-regions of Africa because a fairly dependable improved technology exists for producing the crop in the region (Abalu, 2001). The maize belt in Africa is broad, extending from Southern Africa through Eastern Africa and across the savannah of West Africa. The crop is also adapted to the forest agro-ecologies and derived savannah (Badu-apraku et al., 2010). Maize accounts for about 15% of the total energy intake, representing 72 kg per capita maize consumption of the rural communities in West and Central Africa (FAOSTAT, 2014). Maize yield is still low in Africa compared to that obtainable in the developed countries. Therefore, many scientific efforts have been directed to improve the maize yield in Africa (Badu-apraku et al., 2011). Crop productivity can be improved by planting good quality seeds. Moreover, other production inputs and improved farming technologies are beneficial when high vigour seeds are sown (Goggi et al., 2008; Farshadfar et al., 2012).

Seed quality is mostly determined by seed vigour, which has the potential to influence crop performance through the rapid and uniform establishment and development of normal seedlings. There are several seed quality tests, but none is universally accepted for all kinds of seeds (Powell and Matthews, 2005). A standard germination test informs the farmers about the number of seeds that will produce normal seedlings. A higher germination percentage indicates higher seed vigour (ISTA, 1995). Likewise, the conductivity test measures the leakage of electrolytes into the water in which seeds are soaked to provide the level of seed vigour. High-vigour seeds can reorganise their broken membranes more rapidly and repair any damage better than low-vigour seeds. The test has been widely used in agriculture to measure seed viability and vigour in many crops (AOSA, 1983).

Another aspect of maize seed quality is the seed physical appearance with respect to colour, shape and arrangement, which are essential in designing the seed processing equipment for the handling, conveying, separation, drying, storing and processing of maize seed (Tarighi et al., 2011). Seed size, shape and other physical qualities are important determinants of moisture imbibition and germination of seeds (Balkaya and Odabas, 2002) and grain grading quality. They have also been reported to influence the grain yield of the crop (Kesavan et al., 2013; Zhang et al., 2014; Chen et al., 2016). However, breeding efforts on maize have chiefly been focused on yield, but not on seed quality improvement. Seed morphometric analysis involves measuring the dimensions (such as length, width, masses, angle, ratio and area) of seeds. It has been widely used to discriminate cultivars of many crops (Geetha et al., 2011; Grillo et al., 2011; Daniel et al., 2012). Geetha et al. (2011), Grillo et al. (2011), Sumathi and Balamurugan (2013) observed that this technique gives information that could be visually obtained repeatedly and faster.

This study, therefore, assessed the variability in and inter-dependence of grain yield, seed morphometric and vigour traits in early maturing hybrid maize. The study will be useful for maize breeders in planning maize improvement programmes, seed companies to discover modern packaging techniques and fabricators to explore novelty in designing machines for maize production.

Materials and Methods

Experimental location and materials

The trial was conducted in Ibadan, Nigeria (3.56° E; 7.33° N and 168 m above sea level). The location lies in the rainforest-savanna-transition agro-ecology of Nigeria. The mean annual rainfall and temperature of the trial site were 158.3 cm and 25.9°C, respectively. The description of the test location for the period of the trial is shown in Figure 1.

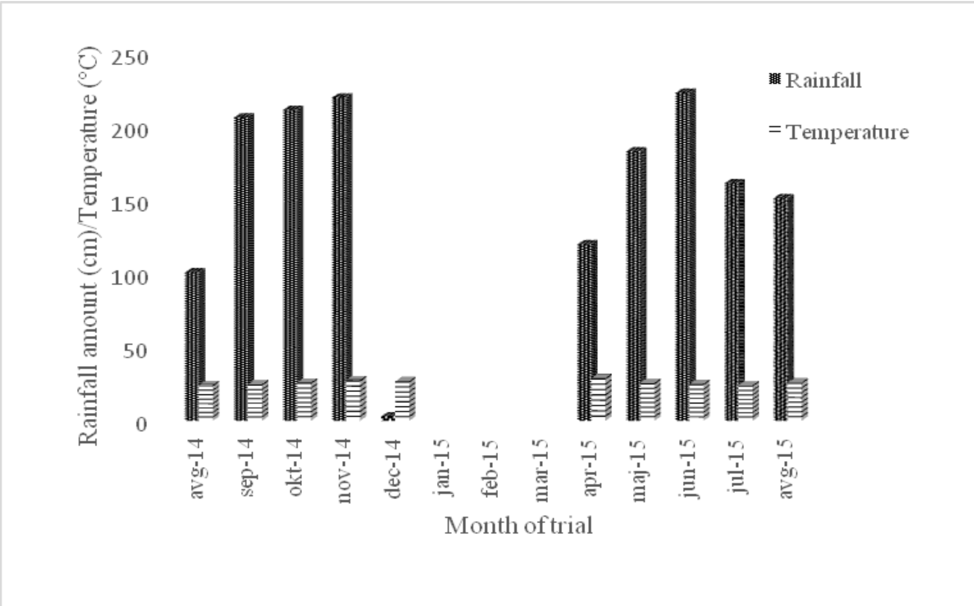

Figure 1. Rainfall and temperature pattern of the site in the period of the field trial.

Seventy-five single cross hybrids of white endosperm maize were evaluated for grain yield and seed quality in a research field and a seed testing laboratory, respectively. The test seeds were obtained from the first filial generation of the single cross hybrid developed in the test location.

Field evaluation for grain yield

The field trial was laid out in a randomised complete block design with three replicates. Each plot consisted of two rows of 5 m long and 0.75 m apart, where plants were spaced 0.5 m in a row. Three seeds were sown and later thinned two weeks after planting (WAP) to two stands per hill to attain a plant population density of 53,333 plants ha^{-1}. Standard cultural practices for field maintenance of maize were applied as recommended by IAR&T (2010). This included ploughing and harrowing of land before planting, applying 60 kg ha^{-1} of N:P:K 15:15:15 fertiliser at 2 WAP and urea as top-dressing at 30 kg N ha^{-1}, two weeks later. The maintenance also involved keeping the field weed-free using herbicides (before plant emergence at 5.0 l ha^{-1} each of paraquat (N, N'-dimethyl-4, 4'-bipyridinuim dichloride) and atrazine (2-Chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine) and hoeing. The crop was protected against pests and diseases by hand picking and destruction of pests. The field evaluation was conducted from August to December 2014 and from April to August 2015. Ears of the plants were harvested when dry. The grains were shelled and weighed, and then the moisture content was determined using a digital moisture tester. The yield data across the two planting seasons were pooled to compute the grain yield using grain moisture content = 15%, harvested plot area = 7.5 m^2, and 1 ha = 10,000 m^2 as follows:

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

where GWT = grain weight and MC = grain moisture content at harvest.

Seed morphometric analysis

Whole and intact 40 seeds were obtained at 10 per ear column from four consecutive ear rows in the middle of the uppermost or only ear of each hybrid maize plant. The seeds were subjected to seed morphometric and quality analyses in four replicates in a laboratory in Ibadan, Nigeria. Ten seeds from each replicate were viewed under a USB microscope one after the other with their embryo axis facing the lens of the camera under the light. The light on the USB microscope was calibrated (×35 magnification) to obtain the brightest image before it was used for measuring the parameters. Morphometric data were taken as described by Grillo et al. (2011) and Geetha et al. (2011), as follows:

- Seed angle (SAG) was the angle created in between two lines touching each other at the tip where the seed is attached to the husk;
- Seed diameter (SDT) was the length of the line drawn across the circle made around the seed;
- Seed thickness (STH) was measured between digital vernier callipers, as the distance between both flat sides of the seed;

- Seed width (SWD) was measured across the middle, and at the right angle to the seed length;
- Seed length (SLG) was the distance between the base of the embryo axis to the tip of the endosperm of the seed;
- Estimations were made on seed area (SAR) as the seed length × seed width.

Seed vigour analyses

Samples were drawn from each seed lot for the standard germination test (SGT), seedling vigour index (SV) and electrical conductivity (EC).

Standard germination test: One hundred seeds were sowed per replicate at 5 cm deep in moistened sterilised river-bed sand inside plastic germination bowls in four replicates under ambient environment. Emerged normal seedlings were counted daily from four to seven days after planting (DAP) according to the procedure laid out by ISTA rules for seed testing. Data were collected on emergence to estimate germination percentage (ISTA, 2009).

Germination percentage (%)

$$= \frac{\text{Number of seedlings emerged at 7DAP}}{\text{Total number of seeds sowed}} \times 100 \qquad (2)$$

Seedling vigour index: The seedling vigour index was estimated using data from the SGT. Ten normal seedlings were randomly selected and carefully uprooted from each replicate at 7 DAP. The seedling lengths were measured for the SVI determination with the germination data in SGT described according to ISTA (2009), using the formula:

$$\text{SVI} = \frac{\text{Seedling length} \times \text{Germination percentage}}{100} \qquad (3)$$

The seedling length was measured as the distance between the base of the plant and the tip of the leaves when folded upward.

Electrical conductivity test: Three replicates of 100 whole and intact seeds per hybrid were weighed. The seeds of each replication were placed in a 200-ml conical flask, and 75 ml of de-ionised water was added. All the flasks were covered by polythene to avoid contaminations and left at ambient temperature in the laboratory for 24 hours. The electrical conductivity of leachates was measured by using a conductivity meter and conductivity per gram of seed weight ($\mu scm^{-1}\ g^{-1}$). The EC was calculated as:

$$\frac{\text{Solution conductivity } (\mu scm^{-1}) \times \text{ control conductivity } (\mu scm^{-1})}{\text{Initial weight of seeds (g)}} \qquad (4)$$

Data analysis

Data collected on grain yield were subjected to the two-way analysis of variance (ANOVA), while data on seed morphometric and vigour traits were analysed using one-way ANOVA. The least significant difference was obtained to separate pairs or groups of means. The relationships among the grain yield, seed morphometric and vigour traits were determined using Spearman's correlation coefficients, while principal component analysis was performed to detect the contributions of each trait to variability among the hybrids.

Results and Discussion

Mean squares, coefficients of variation and range values for the grain yield and seed parameters of the hybrid maize

Significant differences (*P<0.01*) were observed in GY, all the dimension and vigour traits of the seeds of the hybrid maize (Table 1). Coefficients of variation (CVs) were equal to or less than 15% for all the seed traits except SVI. It was higher for GY (23.03%). Moreover, the CV was less than 10.00% for all the morphometric traits and germination percentage. The minimum and maximum values for the seed morphometric and vigour traits were also shown in Table 1.

Table 1. Analysis of variance for grain yield, seed morphometric and vigour traits of hybrids of early maize inbred lines.

Source of variation	Grain yield (kg^{-1})	Seed morphometric trait						Vigour trait		
		Angle (°)	Diameter (cm)	Thickness (cm)	Width (cm)	Length (cm)	Area (cm^2)	GP (%)	Seedling vigour index	EC ($\mu sg^{-1} cm^{-1}$)
Genotype (df=74)	2584109.00***	99.04***	3.28***	0.95***	1.21 ***	3.62***	435.16***	1036.61**	50.97**	20.30**
Block (df=2)	2176083.30	-	-	-	-	-	-	-	-	-
Error	408025.70	27.36	0.25	0.16	0.12	0.46	31.45	0.04	0.00	100.347
CV (%)	23.03	6.66	8.66	9.45	4.82	7.99	9.28	4.88	30.60	15.05
Minimum	2263.80	63.55	6.39	3.07	5.46	6.37	35.05	23.00	4.04	2.50
Maximum	5554.60	92.92	11.25	5.73	8.93	11.15	99.58	100.00	20.10	77.30

GP and EC mean germination percentage and electrical conductivity, respectively. **, *** mean significant at *P<0.001* and *0.0001*, respectively.

There have been several reports of variation in grain yields of early maturing hybrid maize due to their genetic potentials (Badu-apraku et al., 2010; Badu-apraku et al., 2011; Ogunniyan et al., 2018). Similarly, the significant variation among the hybrids in some seed parameters shows variability in the seed vigour quality. Similar results were found in maize for seed vigour, particularly the SVI and EC, and seed morphometry (Peterson et al., 1995; Varga et al., 2012). The low CVs of all the seed morphometric traits in this study show precisions in the experimentation and data collection process. Considering the fairly large number of entries (75 hybrids), the low CVs may also mean consistency of an individual hybrid or suggests that selection through seeds should employ multiple traits. However, the large CVs for the GY and SVI indicate that the parameters may be considered for selection. Wide ranges for the traits also buttressed the nomination of the seed traits as selection indices. Large variability has also been found in the analysis of seedling vigour (Adetumbi, 2013; El-abady, 2015; Ogunniyan et al., 2017).

Grain yield and seed quality traits of the hybrid maize

Grain yield (GY) of the 75 hybrids ranged from 2263.8 kg ha^{-1} to 5554.6 kg ha^{-1} with a mean of 3674 kg ha^{-1} (Appendix 1). However, nine hybrids had GY higher than or equal to 4500 kg ha-[1], while eight had GY less than 3000 kg ha-[1] (Table 2). There were significant differences among the selected 17 high or low yielding hybrids with respect to all the seed traits except SAG and SWD. Three hybrids (BD74-171×BD74-128, BD74-399×BD74-128 and BD74-170×BD74-152) among the eight high yielding hybrids had high values of SAG, SDT, STH, SWD, SLG, SAR, GP, SVI and EC, while four of the nine highest yielding hybrids had EC higher than 30.0 $\mu s g^{-1}$ cm^{-1}. Although the three high grain yielding hybrids had the high seed morphometric and vigour traits, the high EC recorded in the hybrids is not a desired trait. Four high yielding hybrids (BD74-170×TZEI4, TZEI1×BD74-399, TZEI188×BD74-171 and TZEI136×BD74-399) had high values for all the seed morphometric traits, GP and SVI, but low value for EC (less than 15%). Therefore, the hybrids were more promising than the others due to their high yield potential, high seed morphometric traits, GP and SVI, but a low EC value. This implies that hybrids with high GY potential have big-sized kernels and will be better suited for mechanised farming. Only TZEI7×TZEI2 hybrid consistently had high values for seed morphometric and seedling vigour traits among the low grain yielding hybrids. Similarly, only one hybrid (TZEI 22×TZEI106) had high EC in the low yielding hybrid category.

The high germination and seedling vigour traits coupled with low electrical conductivity identified in the promising hybrids suggest that they can be recommended for seed companies for multiplication and production. Only TZEI7×TZEI2 (about 12.5%) of the low yielding category of the hybrid maize consistently had high values for seed morphometric and vigour traits. This showed the importance of shapes in the final weight of the grains. It has been reported that seed dimension affects seed germination, emergence, seedling vigour and the resultant yield in crop plants and that the large seed improves germination and seedling vigour (Varga et al., 2012; Kesavan et al., 2013; Zhang et al., 2014; El-abady, 2015). Also, seeds of similar dimension are planted or processed using the same equipment because of their uniformity, therefore, the seed morphometric trait becomes an important factor to seed industries as it facilitates processing, grading and packaging. Peterson et al. (1995) have reported that flat seeds have few tendencies to mechanical damage. Four of the nine highest yielding hybrids had EC higher than 30.0 μsg^{-1} cm^{-1}, while only one (TZEI 22× TZEI 106) had high EC. It, therefore, implies that seed vigour parameters can be used concurrently for high precision in seed selection activities.

Table 2. Mean values for grain yield, seed morphometric and vigour traits of eight highest and nine lowest grain yielding hybrids of early maize inbred lines.

Hybrid	GY (kg ha^{-1})	SAG (°C)	SDT (cm)	STH (cm)	SWD (cm)	SLG (cm)	SAR (cm^2)	GP (%)	SVI	EC (μsg^{-1} cm^{-1})
The highest grain yielding										
BD74-170× TZEI 4	**5554.6**	**75.9**	**9.6**	**3.8**	**7.6**	**9.2**	**70.1**	**56.3**	**9.4**	**15.3**
TZEI 1× BD74-399	**5161.5**	**76.6**	**9.2**	**3.8**	**7.4**	**8.9**	**65.9**	**62.0**	**7.4**	**2.6**
BD74-171× BD74-128	5140.4	70.7	10.5	3.2	6.7	10.5	70.5	23.3	4.0	58.6
BD74-170× BD74-55	5051.5	77.0	9.1	4.3	7.3	8.8	64.8	30.0	4.9	61.1
TZEI 188 × BD74-171	**4941.8**	**77.6**	**8.6**	**4.4**	**6.8**	**8.4**	**57.6**	**51.0**	**6.0**	**6.8**
TZEI 136× BD74-399	**4836.6**	**80.0**	**8.3**	**3.4**	**7.0**	**8.6**	**60.1**	**48.3**	**5.8**	**2.5**
BD74-179×BD74-55	4654.3	72.9	8.8	3.1	7.0	8.5	59.6	31.7	4.6	44.4
BD74-170× BD74-152	4533.7	74.1	8.8	4.3	6.1	8.7	53.3	59.0	12.8	23.5
BD74-399× BD74-128	4495.5	73.2	10.4	3.5	7.5	10.4	77.9	36.7	5.8	34.1
The lowest grain yielding										
TZEI 22× TZEI 106	2869.9	84.5	8.1	4.8	7.0	7.6	53.0	23.0	4.1	77.3
TZEI 136× TZEI 3	2869.2	78.0	8.9	4.1	7.2	9.1	65.5	58.7	7.3	8.4
TZEI 98× BD74-55	2847.9	79.4	8.8	3.5	7.3	9.1	66.3	65.7	12.9	13.5
BD74-399× TZEI 3	2786.3	71.7	7.5	3.5	6.2	7.2	44.0	100.0	20.1	13.1
TZEI7× TZEI2	2717.5	76.6	11.3	4.0	8.9	11.2	99.6	75.0	9.1	9.8
TZEI 188 × TZEI 2	2686.8	84.3	7.0	4.2	6.3	7.0	43.8	57.0	11.3	8.1
TZEI 188 × TZEI 106	2576.5	88.6	7.4	4.4	6.9	7.3	50.5	60.3	11.9	11.3
BD74-152× TZEI 136	2263.8	79.2	7.0	4.0	5.9	6.8	39.7	56.0	13.0	11.9
LSD	430.4	8.44	0.8	0.6	0.6	1.1	9.1	14.3	2.8	16.2

GY: grain yield; SAG: seed angle; SDT: seed diameter; STH: seed thickness; SWD: seed width; SLG: seed length; SAR: seed area; GP: germination percentage; SVI: seedling vigour index; EC: electrical conductivity and LSD: Least significant difference. Hybrids highlighted in bold had high grain yield, seed morphometric trait and vigour (low electrical conductivity values).

Relationship between grain yield, seed germination and morphometric traits of the hybrid maize

Various positive and negative significant correlations were found among the GY, seed dimension and vigour traits of the hybrid maize (Table 3). The GY had a highly significant correlation with SAG, while it was positively correlated with SDT, SWD, SLG, SAR and SVI. This shows that both seed dimension and vigour parameters contributed to the GY of the maize. The SAG had significantly negative correlations with three out of five seed traits, namely SDT, SLG and SAR, but it was positively correlated with STH (0.27^{*}). Hence, SAG is vital in the dimension determination and selection in maize. Highly significant positive correlations were found among the SDT, SWD, SLG and SAR. Similarly, SDT, SWD and SLG positively correlated with one another. The SDT is a versatile seed dimension trait for its relationship with SWD, SLG and SAR because SWD and SLG are factors of SAR. The three traits are important in discriminating and selecting hybrid maize seeds. The GP had a highly significant correlation with SVI (0.83^{***}), while correlations of EC with GP (-0.67^{***}) and SVI (-0.45^{***}) were highly significant. It can also be deduced from this result that seed vigour is independent of GY, as shown in the non-correlation of GY with GP, SVI and EC.

Table 3. Spearman's correlations of grain yield, seed morphometric and vigour traits of hybrids of the early maize inbred lines.

	GY	SAG	SDT	STH	SWD	SLG	SAR	GP	SVI
SAG	-0.28^{*}								
SDT	0.40^{***}	-0.58^{***}							
STH	-0.18	0.27^{*}	-0.16						
SWD	0.16^{***}	-0.06	0.69^{***}	0.03					
SLG	0.35^{***}	-0.63^{***}	0.94^{***}	-0.22	0.62^{***}				
SAR	0.30^{**}	-0.44^{***}	0.93^{***}	-0.15	0.84^{***}	0.93^{***}			
GPT	0.09	0.09	-0.11	-0.02	-0.04	-0.12	-0.10		
SVI	0.30^{**}	0.12	-0.21	0.05	-0.16^{*}	-0.20	-0.20	0.83^{***}	
EC	-0.20	-0.21	0.23^{*}	-0.07	0.00	0.23^{*}	0.17	-0.67^{***}	-0.45^{***}

GY: grain yield; SA: seed angle; SDT: seed diameter; STH: seed thickness; SWD: seed width; SLG: seed length; SAR: seed area; GP: germination percentage; SVI: seedling vigour index and EC: electrical conductivity. *, **, *** mean significant at *P<0.05, 0.001* and *0.0001*, respectively.

Principal component analysis

The first four PCs explained a total of 81.47% of the total variance for the GY, seed germination and morphometric parameters (Table 4). The eigenvalue of PC I was 4.5 and was higher than the other three PCs with the values of 2.7, 1.3, and 1.3, respectively. PC I was responsible for about 37.73% of the total variation and was loaded with seed diameter (0.868), seed length (0.860) and seed area (0.849). The second PC was responsible for about 22.16% of the total variation and was majorly loaded with seed vigour index (0.678) and germination percentage (0.662). PCs III and IV captured about 11.0% each of the total variation, while seed thickness (0.663), seed angle (0.602), and seed width (0.534) were more prominent in PC III, and electrical conductivity (0.543) was the only parameter prominent in PC IV.

Table 4. The decomposition of contributions of grain yield, seed morphometric and vigour traits of the hybrids of the inbred lines of early maturing maize into the first four principal component axes.

Trait	Eigenvectors			
	PC I	PC II	PC III	PC IV
Grain yield	0.503	-0.100	-0.293	-0.121
Seed angle	-0.468	-0.321	**0.602**	-0.130
Seed diameter	**0.868**	0.446	0.014	0.088
Seed thickness	-0.225	-0.044	**0.663**	0.391
Seed width	0.674	0.377	0.534	-0.038
Seed length	**0.860**	0.443	-0.068	0.070
Seed area	**0.849**	0.469	0.202	0.012
Germination percentage	-0.463	**0.662**	-0.016	-0.502
Seedling vigour I	-0.634	**0.678**	-0.121	-0.150
Electrical conductivity	0.351	-0.463	-0.246	**0.543**
Eigenvalue	4.528	2.659	1.309	1.281
Percent variance (%)	37.73	22.16	10.91	10.67
Cumulative percent variance (%)	37.73	59.89	70.80	81.47

PC is the principal component.

The first two PCs had the greatest discriminating ability and captured greater than 50% of the contribution of the various parameters to variability in the maize. PC I captured three traits, namely SDT, SLG, and SAR, which are important in determining the performance of the maize. The three seed parameters had a value greater than the value for the GY. This result proved the resourcefulness of PC I and buttressed the relatedness of the traits in agreement with the findings of Ogunniyan (2016), who has also reported the usefulness of PC I in associating traits that can be improved to obtain a higher yield of crops. The discriminating ability of the six traits has supported that both seed dimension and vigour parameters contributed to the GY of the maize as recorded through correlation analysis. Therefore, this study has identified high yielding, white kernel hybrid maize with high germination and seed vigour that can be further multiplied or used to improve seed vigour of other inbred lines in maize breeding programmes.

Conclusion

Four early maturing hybrids with high grain yield ability: BD74-170×TZEI4, TZEI1×BD74-399, TZEI188×BD74-171 and TZEI136×BD74-399 were revealed in this study and recommended for seed companies to explore their yield potential, high values for seed morphometric and vigour quality traits. This study emphasises the importance of multiple traits for higher precision in maize varietal selection using seeds. Seed diameter, seed length and seed area are important dimension traits useful in discriminating and selecting hybrid maize seeds.

References

Abalu, G.I. (2001). Policy issues in maize research and development in sub-Sahara Africa in the next millennium. In: B. Badu-Apraku, M.A.B. Fakorede, M. Ouedaogo, and R.J. Carsky (Eds.), Impact, challenges and prospects of maize research and development in West and Central Africa. *Proceedings of a Regional Maize Workshop* (pp. 3-30). IITA-Cotonou, Benin Republic. WECAMAN/IITA.

Adetumbi, J.A. (2013). Genetic purity of parental inbred lines, commercial hybrids and open pollinated maize (*Zea mays* L.) seed in Nigeria. PhD thesis at the Department of Plant Breeding and Seed Technology, Federal University of Agriculture, Abeokuta. Nigeria.

AOSA (1983). *Association of Official Seed Analysts. Seed vigour testing handbook*. Contribution No. 32. Association of Official Seed Analysts. Lincoln, NE., USA.

Badu-apraku, B., Menkir, A., Ajala, S., Akinwale, R., Oyekunle, M., & Obeng-antwi, K. (2010). Performance of tropical early-maturing maize cultivars in multiple stress environments. *Canadian Journal of Plant Science*, *90*, 831-852.

Badu-apraku, B., Akinwale, R.O., Ajala, S.O., Menkir, A., Fakorede, M.A.B., & Oyekunle, M. (2011). Relationships among traits of tropical early maize cultivars in contrasting environments. *Agronomy Journal*, *103*, 717-729.

Balkaya, A., & Odabas, M.S. (2002). Determination of the seed characteristic in some significant snap beans varieties grown in Samsum, Turkey. *Pakistan Journal of Biological Science,* 5, 382-387.

Chen, J., Zhang, L., Liu, S., Li, Z., Huang, R., Li, Y., Cheng, H., Li, X., Zhou, B., Wu, S., Chen, W., Wu, J., & Ding, J. (2016). The genetic basis of natural variation in kernel size and related traits using a four-way Cross population in maize. *PLoS ONE* 11(4), e0153428.

Daniel, I.O., Adeboye, K.A., Oduwaye, O.O., & Porbeni, J. (2012). Digital seed morphometric characterization of tropical maize inbred lines for cultivar discrimination. *International Journal of Plant Breeding and Genetics, 6*, 245-251.

El-abady, M.I. (2015). Influence of maize seed size/shape, planted at different depths and temperatures on seed emergence and seedling vigour. *Research Journal of Seed Science, 8*, 1-11.

FAOSTAT (2014). Statistical database of the Food and Agriculture. Organization. Available from: http://www.faostat.fao.org. [Accessed 10 April 2016].

Farshadfar, M., Amjadian, M., & Dabiri, S. (2012). The effect of intercropping (corn and soybean) on vigour of seed corn. *Annals of Biological Reserach, 3* (8), 3962-3967.

Geetha, V.V., Balamurugan, P., & Bhaskaran, M. (2011). Characterization of mustard genotypes through image analysis. *Research Journal of Seed Science*, *4*, 192-198.

Goggi, A.S., Petrutza, C., Pollak, L., Mcandrews, G., Devries, M., & Montgomery, K. (2008). Seed quality assurance in maize breeding programs: tests to explain variations in maize populations. *Agronomy Journal*, *100*, 337-343.

Grillo, O., Miceli, C., & Venora, G. (2011). Computerized image analysis applied to inspection of vetch seeds for varietal identification. *Seed Science and Technology*, 39, 490-500.

IAR & T (2010). Institute of Agricultural Research & Training. Farmers' Guide Series 1. No. 4: Guide on maize production. Obafemi Awolowo University, Ibadan.

ISTA (1995). *Handbook of vigour test methods. International Seed Testing Association*. Zurich. Switzerland. 117. Available from: https://www.seedtest.org/en /productdetail-1-1082-203-45.html [Accessed 10 April 2016].

ISTA (2009). *International Rules for Seed Testing. International Seed Testing Association*, Zurich, Switzerland. Available from: https://www.seedtest.org/en/ productdetail-1-1082-203-45.html [Accessed 12 January 2018].

Kesavan, M., Song, J.T., & Seo, H.S. (2013). Seed size: a priority trait in cereal crops. *Physiology Plantae*, *147*, 113-120.

Ogunniyan, D.J. (2016). Assessment of genetic divergence in kenaf (*Hibiscus cannabinus* L.) genotypes using agro-botanical characteristics and multivariate analysis. *SABRAO Journal of Breeding and Genetics, 48* (1), 61-71.

Ogunniyan, D.J., Olasoji, J.O. & Adetumbi, J.A. (2017). Effects of heterosis on seed vigour of white kernel maize (*Zea mays* L.). *Seed Technology, 38* (1), 33-48.

Ogunniyan, D.J., Alake, C.O., Makinde, S.A., & Anjorin, F.A. (2018). Agronomic performance of hybrids of white low-nitrogen maize (*Zea mays* L.) inbred lines under stress and optimum nitrogen environments. *Tropical Agriculture, 95* (1), 18-30.

Peterson, J.M., Perdomo, J.A., & Burris, J.S. (1995). Influence of kernel position, mechanical damage and controlled deterioration on estimates of hybrid maize seed quality. *Seed Science and Technology*, *23*, 647-657.

Powell, A.A., & Matthews, S. (2005). *Towards the validation of the controlled deterioration vigour test for small seeded vegetables*. Seed Testing International Association (ISTA) News Bulletin, *129*, 21-24.

Sumathi, S., & Balamurugan, P. (2013). Characterization of oats (*Avena sativa* L.) cultivars 1using machine vision. *Pakistan Journal Biological Science*, *16*, 1179-1183.

Tarighi, J., Mahmoudi, A., & Alavi, N. (2011). Some mechanical and physical properties of corn seed (Var. DCC 370). *African Journal of Agricultural Research, 6* (16), 3691-3699.

Varga, P., Berzy, T., Anda, A., & Ertsey, K. (2012). Relationship between seed harvesting method and seed physiological quality for a number of Pioneer maize hybrids. *Maydica, 57*, 220-225.

Zhang, Z., Liu, Z., Hu, Y., Li, W., Fu, Z., Ding, D., Li, H., Qiaq, M., & Tang, J. (2014). QTL analysis of kernel-related traits in maize using an immortalized F_2 population. *PLoS One* 9,e89645. doi: 10.1371/journal.pone.0089645.

Received: October 3, 2020
Accepted: May 10, 2021

Appendix 1. Mean values for grain yield, seed morphometric and vigour traits of the hybrids of maize inbred lines.

Hybrid	Grain yield (kg ha^{-1})	SAG (°C)	SDT (cm)	STH (cm)	SWD (cm)	SLG (cm)	SAR (cm^{2})	GP (%)	SVI	EC (µsg^{-1} cm^{-1})
TZEI 1×TZEI 2	2959.9	80.3	7.2*	3.5	6.3	8.0	50.9	41.7	5.68*	28.2
TZEI 1×TZEI 98	3235.5	77.0	9.4	5.4**	7.5	9.2	68.8	48.3	6.62	16.2
TZEI 1×TZEI 106	3299.4*	78.3	8.2	4.1	7.0	8.8	61.1	40.3	8.00	9.8*
TZEI 7×TZEI 2	2717.5	76.6	11.3**	4.0	8.9**	11.2**	99.6**	75.0**	9.10	9.8*
TZEI 7×TZEI 3	3996.2*	79.5	9.3	4.0	7.2	8.7	62.6	53.3	6.35	6.7*
TZEI 7×TZEI 4	2966.2	76.8	9.0	3.6	7.1	9.6**	68.9	44.3	9.61	23.4
TZEI 7×TZEI 98	3373.6*	71.8	10.2**	3.4*	7.3	10.5**	76.5	35.0*	4.98*	22.5
TZEI 22×TZEI 2	3211.8	84.2	7.8*	4.9**	6.7	7.5	49.8*	37.7*	5.62*	12.2
TZEI 22×TZEI 3	3038.7	83.1	8.1	3.8	7.3	8.4	61.4	61.7	11.66**	9.0*
TZEI 22×TZEI 98	3226.5	75.8	9.5**	3.9	7.3	9.2	66.7	50.7	10.38	31.9
TZEI 22×TZEI 106	2869.9	84.5	8.1	4.8**	7.0	7.6	53.0	23.0*	4.13*	77.3**
TZEI 136×TZEI 2	3318.5*	74.5	9.1	3.5	7.3	9.1	66.3	45.7	4.20*	18.5*
TZEI 136×TZEI 3	2869.2	78.0	8.9	4.1	7.2	9.1	65.5	58.7	7.30	8.4*
TZEI 136×TZEI 98	3828.0*	83.8	8.7	3.7	6.9	8.4	57.6	64.3	9.90	8.6*
TZEI 188×TZEI 2	2686.8	84.3	7.0*	4.2	6.3	7.0*	43.8*	57.0	11.32**	8.1*
TZEI 188×TZEI 3	3436.0*	72.7	8.6	4.0	7.1	8.5	60.3	63.0	9.11	4.7*
TZEI 188×TZEI 106	2576.5	88.6**	7.4*	4.4	6.9	7.3*	50.5*	60.3	11.91**	11.3*
BD74-152×TZEI 1	3202.2	82.2	6.6*	4.4	5.5*	6.4*	35.1*	84.3**	14.46**	8.8*
BD74-152×TZEI 7	3215.2	77.8	8.4	4.1	7.6**	8.3	62.6	27.0*	4.04*	58.9**
BD74-152×TZEI 22	3392.1*	89.2**	7.3*	4.2	6.8	6.6*	45.1*	54.0	11.34**	7.5*
BD74-152×TZEI 136	2263.8	79.2	7.0*	4.0	5.9*	6.8*	39.7*	56.0	12.96**	11.9*
BD74-152×TZEI 188	3736.1*	84.2	8.5	4.2	7.5	8.3	62.4	95.3**	18.75**	7.5*
BD74-147×TZEI 7	4078.9*	79.4	9.0	3.8	6.9	8.2	56.4	61.0	7.19	5.7*
BD74-147×TZEI 22	3492.8*	90.0**	7.7*	5.2**	7.4	7.9	58.5	63.7	8.47	3.7*
BD74-147×TZEI 188	3457.5*	77.7	9.0	3.8	8.0**	8.9	71.4**	77.0**	15.22**	2.7*
BD74-31×TZEI 1	3249.8*	82.0	7.2*	4.1	6.2*	7.1*	44.4*	90.0**	17.34**	3.5*
BD74-31×TZEI 7	3772.4*	76.4	7.3*	3.7	6.1*	7.8	48.3*	99.7**	17.24**	2.9*
BD74-31×TZEI 188	3026.0	81.6	7.5*	4.3	6.6	7.7	50.7*	65.7	9.44	2.5*
BD74-55×TZEI 1	2916.4	80.4	7.6*	4.0	6.5	7.4	47.6*	68.0	7.68	3.2*
BD74-55×TZEI 7	3359.5*	80.7	7.3*	4.0	6.3	7.1*	45.2*	44.0*	4.57*	20.1
BD74-55×TZEI 22	3432.3*	89.0**	8.4	5.2**	8.1**	7.5	60.7	52.3	9.36	3.0*
BD74-55×TZEI 136	3466.3*	80.0	7.8*	4.5	5.9	7.3*	43.4*	67.0	13.34**	4.1*
BD74-55×TZEI 188	4160.5**	84.4	9.0	3.4*	8.0**	8.7	70.0**	78.7**	10.07	2.6*
TZEI 1×BD74-170	3849.3*	72.9	10.3**	3.5	8.2**	10.1**	82.9**	62.0	6.76	3.1*
TZEI 1×BD74-171	4135.9**	76.3	8.6	4.2	6.8	8.5	57.8	62.7	8.80	3.9*
TZEI 1×BD74-399	5161.5**	76.6	9.2	3.8	7.4	8.9	65.9	62.0	7.38	2.6*
TZEI 7×BD74-170	4184.6**	72.8	9.6**	3.3*	7.4	9.5	69.9**	55.3	5.90*	5.2*
TZEI 7×BD74-171	3570.1*	68.8*	9.9**	4.7**	7.1	9.8**	69.9**	40.3	6.12	15.5
TZEI 7×BD74-179	4078.7*	80.9	8.8	5.6**	7.4	8.4	62.2	56.3	8.33	4.8*

Continued – Appendix 1. Mean values for grain yield, seed morphometric and vigour traits of the hybrids of maize inbred lines.

Hybrid	Grain yield (kg ha-1)	SAG (°C)	SDT (cm)	STH (cm)	SWD (cm)	SLG (cm)	SAR (cm2)	GP (%)	SVI	EC (μsg-1 cm-1)
TZEI 136×BD74-399	4836.6**	80.0	8.3	3.4*	7.0	8.6	60.1	48.3	5.81*	2.5*
TZEI 188×BD74-170	4354.9**	77.2	10.9**	3.7	8.3**	10.9**	90.1**	47.0	6.67	15.0
TZEI 188×BD74-171	4941.8**	77.6	8.6	4.4	6.8	8.4	57.6	51.0	6.01	6.8*
TZEI 188×BD74-175	3897.0*	71.4	7.8*	5.7**	6.4	7.6*	48.7*	40.3	7.85	11.2*
TZEI 4×BD74-152	3737.4*	87.7*	7.2*	4.2	6.6	6.5*	43.0*	41.7	6.44	8.9*
TZEI 98×BD74-31	3069.9	71.9	8.3	3.1*	6.6	8.1	53.8	31.7*	5.53	19.0
TZEI 98×BD74-55	2847.9	79.4	8.8	3.5	7.3	9.1	66.3	65.7	12.87**	13.5
TZEI 106×BD74-55	3564.5*	83.9	9.0	3.9	7.9**	8.5	66.7	59.0	12.30**	22.8
BD74-170×TZEI 2	4251.1**	63.6*	9.0	3.4*	6.3	9.6**	60.3	43.0	7.30	52.6
BD74-170×TZEI 3	3891.4*	79.2	9.8**	4.2	7.5	9.7**	72.9**	36.3*	5.47*	67.8**
BD74-170×TZEI 4	5554.6**	75.9	9.6**	3.8	7.6**	9.2	70.1**	56.3	9.40	15.3
BD74-170×TZEI 98	4317.6**	77.0	9.3	3.7	6.8	9.8**	66.9	44.3	8.05	19.1
BD74-171×TZEI 2	3789.4*	73.7	10.4**	4.4	7.2	10.5**	74.4**	56.3	9.11	24.3
BD74-171×TZEI 3	3214.9	80.1	9.2	3.9	7.0	8.7	61.5	87.3**	18.09**	11.7*
BD74-171×TZEI 4	4003.5**	89.4**	8.8	4.5	7.5	8.9	66.7	36.3*	4.77*	33.9
BD74-171×TZEI 106	3739.0*	85.8	7.5*	4.0	6.5	7.0*	45.1*	51.7	7.58	21.3
BD74-179×TZEI 3	3662.6*	80.6	8.3	3.4*	6.6	8.2	54.0	59.0	9.61	22.0
BD74-179×TZEI 4	3172.7	83.5	8.5	4.0	6.8	7.7	52.6	33.7*	5.58*	43.9
BD74-179×TZEI 98	4115.3**	79.2	8.9	3.3*	7.4	8.4	61.9	24.3*	4.31*	71.0**
BD74-175×TZEI 98	3548.1*	71.9	8.7	3.8	6.4	8.6	55.6	41.7	7.04	19.1
BD74-399×TZEI 2	3634.9*	71.0	9.1	3.4*	7.0	8.9	62.3	85.7**	14.28**	38.1
BD74-399×TZEI 3	2786.3	71.7	7.5*	3.5	6.2*	7.2*	44.0*	100.0**	20.10**	13.1
BD74-399×TZEI 98	3458.3*	83.2	6.4*	4.1	5.6*	6.4*	35.9*	53.7	10.61	42.7
BD74-170×BD74-152	4533.7**	74.1	8.8	4.3	6.1*	8.7	53.3*	59.0	12.78**	23.5
BD74-170×BD74-55	5051.5**	77.0	9.1	4.3	7.3	8.8	64.8	30.0*	4.85*	61.1**
BD74-170×BD74-128	4236.3**	67.8*	10.0**	4.3	7.0	9.8**	67.9	60.3	9.30	47.4
BD74-171×BD74-152	3535.1*	71.2	9.5**	4.5	7.3	9.4	68.6	55.0	10.31	38.1
BD74-171×BD74-31	3347.1*	75.0	9.8**	4.6	7.7**	9.7**	74.6**	40.3	8.24	40.7
BD74-171×BD74-55	4233.7**	92.9**	7.2*	3.5	6.6	7.4	48.4*	24.0*	4.08*	76.6**
BD74-171×BD74-128	5140.4**	70.7	10.5**	3.2*	6.7	10.5**	70.5**	23.3*	4.04*	58.6**
BD74-179×BD74-147	3547.4*	81.4	9.2	3.8	7.5	8.9	67.2	95.0**	16.44**	12.4
BD74-179×BD74-55	4654.3**	72.9	8.8	3.1*	7.0	8.5	59.6	31.7*	4.62*	44.4
BD74-175×BD74-55	4138.2**	78.1	8.3	4.3	6.7	8.0	53.2	36.7*	4.38*	57.7**
BD74-399×BD74-147	4312.1**	72.0	9.8**	4.4	8.0**	9.7**	77.3**	58.0	5.48*	13.8
BD74-399×BD74-55	3130.8	80.8	9.1	4.9**	7.8**	8.7	67.3	30.7*	4.18*	50.6
BD74-399×BD74-128	4495.5**	73.2	10.4**	3.5	7.5	10.4**	77.9**	36.7*	5.76	34.1
Mean	3674.1	78.56	8.7	4.1	7.0	8.5	60.5	54.1	8.8	21.9
LSD	430.4	8.44	0.8	0.6	0.6	1.1	9.1	14.3	2.8	16.2

GY, SAG, SDT, STH, SWD, SLG, SAR, GP, SVI and EC mean grain yield, seed angle, seed diameter, seed thickness, seed width, seed length, seed area, germination percentage, seedling vigour and electrical conductivity, respectively. * and ** mean lower and higher than mean values, respectively.

PROMENLJIVOST PRINOSA ZRNA, MORFOMETRIJSKIH I OSOBINA ŽIVOTNE SPOSOBNOSTI SEMENA RANOG HIBRIDNOG KUKURUZA

Dotun J. Ogunniyan[1*], Johnson A. Adetumbi[1], Julius O. Olasoji[1] i Solomon A. Makinde[2]

[1]Institut za poljoprivredna istraživanja i obuku, Univerzitet Obafemi Awolowo, Moor Plantation, Ibadan, Nigerija
[2]Odsek za oplemenjivanje biljaka i tehnologiju semena, Savezni poljoprivredni univerzitet, Abeokuta

R e z i m e

Oplemenjivanje radi prinosa i kvaliteta zahteva procenu pokazatelja i osobina životne sposobnosti semena. Stoga je ovom studijom procenjena promenljivost i međuzavisnost prinosa zrna (PZ), morfometrijskih i osobina životne sposobnosti semena kod hibridnog kukuruza. Semena 75 linija ranog hibridnog kukuruza ocenjena su u pogledu morfometrijskih osobina i kvaliteta u četiri ponavljanja. Poljski ogled izveden u potpuno slučajnom blok sistemu sa tri ponavljanja takođe je sproveden u Ibadanu (Nigerija), kako bi se utvrdio prinos zrna hibrida. Podaci prikupljeni o PZ, dimenziji i kvalitetu semena obrađeni su analizom varijanse. Najmanje značajna razlika korišćena je za poređenje srednjih vrednosti. Odnosi između PZ, morfometrijskih i osobina životne sposobnosti semena utvrđeni su pomoću koeficijenata korelacije, dok je analiza glavnih komponenti (GK) primenjena radi utvrđivanja promenljivosti među hibridima. Značajne razlike (*P<0,001*) utvrđene su kod PZ, dimenzija semena i osobina životne sposobnosti semena. Četiri od devet hibrida sa najvišim prinosom imali su ECT veći od 30,0 $\mu s g^{-1} cm^{-1}$. PZ je korelirao sa prečnikom semena (0,40**), širinom semena (0,36**), dužinom semena (0,35**), površinom semena (0,30**) i životnom sposobnošću semena (0,30**). Ugao semena korelirao je sa prečnikom semena, dužinom semena, debljinom semena i površinom semena. Sve osobine životne sposobnosti semena korelirale su jedna s drugom. Prvom glavnom komponentom objašnjen je prinos zrna, prečnik semena, širina semena, dužina semena, površina semena i životna sposobnost semena, ukazujući na njihovu važnost kod poboljšanja prinosa zrna. Ugao, dužina i prečnik semena bili su promenljivi kod izbora varijeteta kukuruza. Semenske kompanije mogle bi istražiti identifikovane hibride visokog prinosa sa morfometrijskim i kvalitetima životne sposobnosti semena kao inovaciju u proizvodnji semena.

Ključne reči: svojstvene vrednosti, električna provodljivost, prinos kukuruza, pokazatelji u vezi sa semenom, životna sposobnost semena.

Primljeno: 3. oktobra 2020.
Odobreno: 10. maja 2021.

*Autor za kontakt: e-mail: dotunogunniyan@yahoo.com