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SEED AND SEEDLING VIGOUR IN TROPICAL MAIZE INBRED LINES

ABSTRACT

Seed and seedling vigour is an aspect of seed quality which affects field establishment and performance. Low maize yields have been reported to be affected by several factors in which poor quality seed with low seed and seedling vigour. Information is scarce on seed and seedling vigour in maize inbred lines developed for tropical environments. Fifteen genotypes of tropical maize (*Zea mays* L.) inbred lines were evaluated to determine the level of differences in seed and seedling vigour traits, and extent of relationships among traits and their heritability. A substantial amount of genetic variability was found, which suggested that most of the traits under study could be improved through selection and utilized in breeding programs. Positive and significant interrelationship among seed germination and seedling traits and a positive correlation between seed germination and seed vigour and field emergence showed that these could be given due consideration in crop improvement for seed and seedling vigour. High genotypic coefficient of variation, heritability and genetic advance were obtained for seed germination, seed emergence, shoot length and seedling vigour index I and II, revealing the possibility of improvement in these characters through direct selection. The principal component analysis (PCA) identified seed emergence, shoot length, seedling vigour index I and II and tetrazolium vigour as characters that contributed greatly to variation in seed vigour in the maize inbred lines. Cluster analysis partitioned the genotypes into two groups, with group I consisting of seven genotypes and group II comprised the other eight genotypes, which suggested that hybridization between the two groups could lead to high level of heterosis. Genotype V_5 had superior seedling vigour traits compared to other genotypes. Seedling emergence, shoot length, seedling vigour index I, seedling vigour index II and tetrazolium vigour are effective characters for good seedling vigour traits in maize inbred lines investigated.

Key words: correlation, genetic advance, heritability, seed quality, variability

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INTRODUCTION

Maize is the most important cereal in the world after wheat (*Triticum aestivum* L.) and rice (*Oryza sativa*, L) in cultivated areas and total production (Purseglove, 1992; Osagie and Eka, 1998). In Nigeria, it is the third most important cereal crop and is grown largely in the rainforest and guineas savannah vegetation zones. The USA is the single largest producer of the crop in the world. Some continents with larger production include Europe, Africa, Asia, and Latin America. Every part of maize plant has economic value; the grain, leaves, stalk, tassel and cobs can all be used to produce a large variety of food and non-food products.

Seed quality components depend on the genetic characteristics of the plants, but seed quality is also strongly affected by the seed development conditions of on the female plants, harvesting and handling procedures as well as storage conditions (Adebisi, 1999 and Adebisi and Ojo, 2001). Most of the seed quality characteristics are polygenically inherited and will therefore be influenced by the environment to a large extent (Labuschangne *et al.* 2002; Adebisi, 2004). Good seed quality relates to the characteristics of seeds that result in high field performances and eventually high seed/grain yield (Adebisi, 2004). One important component of seed quality is seed/seedling vigour, which is defined as the sum total of those properties of the seed that determine the level of activity and performance of the seed or seed lot during germination and seedling emergence (Hampton and Tekrony, 1995). Vigour test represents significant technological advances in seed quality control. Adeyemo and Fakorede (1995) and Mponda *et al.* (1997) have shown that seedling vigour can also be a selection criterion when breeding for improved seed yield in crops.

An inbred line results from 5 to 7 generations of inbreeding. At most loci, its growth characters are fixed in a homozygous condition. Genetic differences are important to plant breeder because without variation there would be no selection and without selection there would be no heritable plant improvement. Therefore, breeders' job is to select those heritable variations that would be useful in the improvement of a crop species.

Seed vigour is an important aspect of quality, which controls field stand, establishment ability and performance. The problems associated with establishing vigourously growing maize seedlings are often related to poor seed quality. High quality maize seeds have the capacity to produce vigourous seedlings across a wide range of environments. Low maize yields have been reported in Nigeria, and several factors, among which is poor quality seed with low seed vigour, have been identified. Information on seed and seedling vigour levels among the tropical maize inbred lines, extent of relationship among seed and seedling vigour characters and their heritability pattern are necessary for maize seed improvement in Nigeria.

Research has been published on agronomic and morphological traits in maize and grain yield (Odiemah, 1995; Munamava *et al.,* 2004; Jalata *et al.,* 2011). Moreover, physiological studies on seedling traits of young plants are also available (Adebisi *et al.*, 2006). However, information on the variability of seedling vigour characters in maize inbred lines developed for tropical environments is limited. Therefore, this study was undertaken to determine the extent of genetic variability in seed and seedling vigour characteristics, to investigate the magnitude of heritability and genetic advance for these seed quality traits and to determine the relationships among seed and seedling characters and their influence on germinability, seedling vigour and finally on field emergence of maize inbred lines.

MATERIALS AND METHODS

Seed material

Seeds of 15 maize inbred lines were obtained from the Maize Research Unit, International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria for the study (Table 1). Seeds of these genotypes were selected on the basis of information grain yield (moderate to high) and other agronomic characters.

Table 1

Pedigree of 15 (V_1-V_{15}) of maize inbred lines used in the study

Pedigree	Source
V_1[(4001 × 9848) x 4001]–1-1-2-B-B-B-1-B-B-B-B-B-B-B-B	IITA, Ibadan
V_2 (9071 × 4058) –8-2-1-1-B-B-B	IITA, Ibadan
V_3 (MP420 × 4001Xmp420) –3-1-2-1-B-B-B-B-B-B-B	IITA, Ibadan
V_4 (1368 × 1824) –4-2-2-1-2-B-B-B	IITA, Ibadan
V_5 (4001 × 9848x4001)-29-1-4-B-1-B-B-B-B-B-B-B-B	IITA, Ibadan
V_6 Obantapa –10-3-2-1-B-B-B-B-B-B-B-B-B-B-B-B	IITA, Ibadan
V_7 Obantapa –23-3-1-B-B-B-B-B-B-B-B-B-B-B-B-B	IITA, Ibadan
V_8 (Ku1414 × 9450)-24-2-1-B-B-B-1-B-B-B-B-B-B-B-B	IITA, Ibadan
V_9 –AG Seeds-361-1-1-1-B-B-B-B-B-B-B-B-B-B-B-B	IITA, Ibadan
V_{10} 4001	IITA, Ibadan
V_{11} TZB-SR	IITA, Ibadan
V_{12} (9071 × 5057)-3-2-1-1-B-B-B	IITA, Ibadan
V_{13} Pioneer Seeds -26-2-1-B-B-B-B-B-B-B-B-B-B	IITA, Ibadan
V_{14} (1368 × 9091)-8-1-3-1-2-B-B-B	IITA, Ibadan
V_{15} (BR9943-DMR-SR	IITA, Ibadan

IITA- International Institute of Tropical Agriculture

Experimental Site and Design

The experiments were carried out in the Seed Laboratory, Department of Plant Breeding and Seed Technology, Federal University of Agriculture, Abeokuta (Latitude 7.1^0N and longitude 3.2^0E), Ogun State and also in a screen house of the same University in May- June 2008. Experiments were repeated in October–November, 2009. A completely randomized design with three replicates was used for the laboratory tests, whereas in the screen house, the genotypes were sown in plastic pots (size 30 cm height, 15 cm diameter) in a randomized complete block design with three replicates.

Seed Quality Assessment

Seed germination and seedling vigour characters of the maize inbred line were evaluated in the laboratory and in the screen house as it is indicated below.

Standard Germination

One hundred seeds replicated three times from each genotype were placed in Petri dishes lined with moistened paper towels at 25°C temperature in an incubator (ISTA, 1995). Seed germination test was determined as follows:

$$SG = \frac{N_{G\,7}}{N_S} \times 100$$

where SG – standard germination, $N_{G\,7}$ – number of seeds germinated after 7 days and N_S – number of seeds sown

Root and shoot lengths of 10 randomly selected seedlings from seed germination test described above were measured in cm on the 10th day. Also, after 10 days, fresh weights of 10 randomly selected seedlings from each replicate from the seed germination test described above were measured. Seedling dry weight of the 10 seedlings from each replicate were also determined by drying the seedlings for 1 hr in an oven at 130°C and then measured in grammes using sensitive weigh balance. The seedling growth rate per day was determined by dividing seedling dry matter by 10 (10 days of evaluation) to determine seedling dry matter. Seedling vigour index I was determined as (Okelola, 2005):

$$SVI_I = \frac{S_{eed}E \times P_l}{100}$$

where SVI_I – seedling vigour index I, $S_{eed}E$ – seed emergence, P_l – plumule length (root and shoot length)

Seedling Vigour Index II was determined as:

$$SVI_{II} = \frac{MDM_{per\ seedling} \times SG}{100}$$

where SVI_{II} – seedling vigour index II, $MDM_{per\ seedling}$ – mean dry matter per seedling, SG – standard germination

Tetrazolium vigour test

A 100% solution of tetrazolium powder in 100 ml of distilled water was prepared, and then 1% concentration of the above solution (i.e., 1 ml of solution in 99 ml of distilled water) was prepared. Fifty seeds of each genotype were soaked in a glass beaker in 200 ml of the 1% solution for 24 hrs at 30°C. Viable seeds were determined as seeds that were completely stained, whereas unstained seeds were regarded as non-viable (Adebisi, 2004).

Seed Weight

Weight of 100 seeds was determined for each genotype in three replicates.

Seedling Emergence

Three hundred seeds of each genotype were sown in pots (100 seeds per pot) in the screen house. Seedling emergence was determined after 10 days according to the equation of ISTA (1995) as follows:

$$S_gE_{10} = \frac{N_{sgE10}}{N_{SP}} \times 100$$

where S_gE_{10} – seedling emergence, N_{sgE10} – number of seedlings emerged after 10 days, N_{SP} – number of seeds planted

Data analysis

Data on each trait were subjected to the following statistical analyses using SPSS statistical software version (16.0): Analysis of variance (ANOVA) was used to determine whether or not genotypic effect was significant. Tukey HSD test was used for mean separation for each trait. Genotypic, phenotypic and error variances were computed (Wricke and Weber,1986; Prasad *et al.,* 1987) as follows:

$$V_g = MSG + \frac{MSE}{r}$$

$$V_p = \frac{MSG}{r}$$

$$V_e = \frac{MSE}{r}$$

where *MSG* is the mean squares of genotypes, *MSE* is the mean squares of error and *r* is the replication number.

Using the formula of Burton (1952) as reported by Kumar *et al.* (1998), phenotypic (*PCV*) and genotypic (*GCV*) coefficients of variation were computed as follows:

$$PCV = \frac{\sqrt{V_p}}{\bar{X}} \times 100$$

$$GCV = \frac{\sqrt{V_g}}{\bar{X}} \times 100$$

where *Vp* (phenotypic variance) *Vg* (genotypic variance) and *X* (grand mean) for the characters considered.

Broad-sense heritability (h^2_B) in percentage, which is the proportion of the genotypic variance (*Vg*) to the phenotypic variance (*Vp*), was estimated on a genotypic mean basis (Allard, 1999). Expected genetic advance (*GA*) and $GA_{M\%}$ (genetic advance as percent of the mean) assuming selection of the superior 5% of the genotype were computed (Kumar *et al.* 1998) as follows:

$$GA = K \times S_p \times H_B^2$$

$$GA_{M\%} = \frac{GA}{\bar{X}} \times 100$$

where K is constant (which varies depending upon selection intensity, and if the latter is 5%, K= 2.06). Sp is the phenotypic standard deviation, H^2_B is the heritability and X is the trait mean. To identify traits mostly responsible for variation among the 15 genotypes, principal component analysis was carried out. Correlation coefficients were determined among the traits to determine the extent of relationships among the various traits. Cluster analysis was employed using seed germination data.

RESULTS AND DISCUSSION

Table2

Summary of analysis of variance showing mean square values of seed and seedling vigour traits in 15 maize inbred lines

1	2	3	4	5	6	7	8	9	10	11	12	13
Replication	2	72.21^{ns}	585.43**	0.42^{ns}	5.98**	30935.53^{ns}	2.79^{ns}	21.47^{ns}	13.14^{ns}	0.0035^{ns}	0.093^{ns}	0.001^{ns}
Trial [T]	1	3986.68^{ns}	3686.40^{ns}	1126.85^{ns}	3.22**	1761928.61^{ns}	4012.17^{ns}	979047.41^{ns}	14212.90^{ns}	1.45 ^{ns}	31.05^{ns}	0.015^{ns}
Variety [V]	14	1623.12**	1733.12**	16.58^{ns}	12.85**	685401.34**	51.73**	2920.00**	251.04**	0.0073^{ns}	0.14**	0.001^{ns}
T × V	14	100.00^{ns}	120.30^{ns}	34.00^{ns}	7.95^{ns}	532785.60**	61.51^{ns}	20.61^{ns}	26.83^{ns}	0.029 ^{ns}	0.34^{ns}	0.001^{ns}
Error	58	81.68	103.74	8.87	0.97	118117.03	1.99	37.44	85.80	0.0053	0.043	0.001

** significant at 1% level of probability; * significant at 5% level of probability; ns – not significant
numbers in the first row refer to:

1 — Source of Variation,
2 — Degree of Freedom,
3 — Seed germination [%],
4 — Seed Emergence [%],
5 — Root Length [cm],
6 — Shoot Length [cm],
7 — Seedling Vigour Index I,
8 — Seedling Vigour Index II,
9 — 100 – Seed Weight[g],
10 — Tetrazolium vigour Test [%],
11 — Seeding Dry Weight [g],
12 — Seeding fresh weight [g],
13 — Seedling Growth Rate [g × day^{-1}]

A summary of analysis of variance for seed and seedling vigour characters in 15 maize inbred lines studied is given in Table 2. Genotype effect was significant for all the parameters evaluated, except root length, seedling dry weight and seedling growth rate. The trial effect was significant for all the parameters evaluated except shoot length. However, the interaction effect of trial and genotype was not significant for all the parameters evaluated except seedling vigour index I. The data also revealed that the significant differences observed in the 11 characters from the 15 maize inbred lines evaluated indicated that variation existed among the 15 genotypes studied. The significant differences among the genotypes for these characters further revealed that selection for these characters among the maize inbred lines for further improvement would be possible because of large variability present. Also, differences observed for the 11 traits may be attributed to diverse genetic backgrounds of the maize inbred lines studied. The results suggested the possibility of improving seed and seedling vigour characters through genotypic selection. The possibility of improving seed quality through genotype selection has been reported by Adebisi (2004) in sesame, Okelola (2005) in NERICA rice and Kehinde *et al.* (2005) in West African okra due to the presence of variability among the test genotypes

Table 3

Mean performance for seed and seedling vigour of 15 maize inbred lines

1	2	3	4	5	6	7	8	9	10	11	12
V_1	81.67^{abcd}	67.17^{bcde}	8.07^{a}	6.72^{ce}	1186.82^{abc}	10.49^{ab}	108.34^{g}	72.67^{ab}	0.30^{a}	1.19^{ab}	0.0301^{a}
V_2	88.00^{ab}	75.17^{ab}	10.59^{a}	6.15^{de}	141269^{abc}	10.91^{ab}	125.96^{def}	75.83^{ab}	0.29^{a}	1.14^{abc}	0.0298^{a}
V_3	65.67^{de}	28.67^{f}	9.25^{a}	7.33^{bcde}	1095.87^{bc}	5.84^{d}	82.82^{h}	72.17^{ab}	0.26^{a}	1.07^{abc}	0.0261^{a}
V_4	83.00^{abcd}	75.33^{ab}	9.90^{a}	5.69^{e}	1240.54^{abc}	12.68^{a}	143.44^{de}	79.83^{ab}	0.35^{a}	1.16^{ab}	0.0348^{a}
V_5	94.00^{a}	91.00^{a}	10.44^{a}	8.22^{abc}	1745.17^{ab}	12.77^{a}	136.01^{ef}	82.00^{ab}	0.36^{a}	1.13^{abc}	0.0359^{a}
V_6	92.67^{a}	71.50^{abcd}	10.08^{a}	8.02^{abcd}	1647.93^{ab}	10.69^{ab}	115.41^{fg}	72.67^{ab}	0.33^{a}	1.08^{abc}	0.0329^{a}
V_7	79.00^{abcd}	60.50^{cde}	9.01^{a}	6.63^{cde}	1314.51^{abc}	12.39^{a}	141.24^{e}	86.00^{ab}	0.27a	0.91^{bc}	0.0268^{a}
V_8	69.00^{cde}	51.83^{cde}	6.55^{a}	6.72^{cde}	921.80^{c}	12.33^{a}	158.24^{c}	71.67^{b}	0.29a	0.86^{bc}	0.0288^{a}
V_9	80.00^{abcd}	57.83^{bcde}	8.86^{a}	5.46^{ef}	1064.66^{bc}	9.92^{abc}	133.08^{cd}	79.67^{ab}	0.34a	1.18^{ab}	0.0342^{a}
V_{10}	89.67^{ab}	66.33^{bcd}	10.34^{a}	7.33^{bcde}	1332.28^{abc}	11.79^{ab}	124.14^{def}	70.00^{b}	0.31a	1.19^{ab}	0.0308^{a}
V_{11}	72.67^{bcde}	69.50^{bcd}	12.59^{a}	7.37^{abcde}	1421.74^{abc}	9.13^{bc}	120.21^{efg}	88.67^{ab}	0.32a	1.35^{a}	0.0320^{a}
V_{12}	85.00^{abc}	51.67^{de}	11.98^{a}	9.36^{a}	1799.70^{a}	8.96^{bc}	131.26^{cde}	91.00^{a}	0.25a	0.73^{c}	0.0350^{a}
V_{13}	91.33^{a}	72.50^{abc}	12.14^{a}	8.82^{ab}	1881.72^{a}	10.41^{ab}	110.96^{g}	78.33^{ab}	0.32a	1.08^{abc}	0.0318^{a}
V_{14}	57.83^{e}	48.00^{ef}	7.91^{a}	6.13^{de}	852.04^{c}	7.07^{cd}	154.16^{cd}	82.00^{ab}	0.36a	1.16^{ab}	0.0364^{a}
V_{15}	31.67^{f}	30.00^{f}	10.41^{a}	3.46^{f}	841.17^{c}	2.09^{e}	170.80b	75.60^{ab}	0.34a	1.20^{ab}	0.0335^{a}
Mean	77.41	61.13	9.87	6.89	1317.24	9.83	130.40	78.54	0.31	1.09	0.0310

Means followed by the same letter within a column are not significantly different from one another according to Duncan Multiple Range Test (1955) at 5% probability level; numbers in the first row refer to:

1 — Variety,
2 — Seed Germination [%],
3 — Seedling Emergence [%],
4 — Root Length [cm],
5 — Shoot Length [cm],
6 — Seedling Vigour Index I,
7 — Seedling Vigour Index II,
8 — 100 Seed Weight [g],
9 — Tetrazolium vigour [%],
10 — Seedling Dry Weight [g],
11 — Seedling Fresh Weight [g],
12 — Seedling Growth Rate [g × day^{-1}]

The mean seedling vigour traits of 15 genotypes of maize inbred lines are presented in Table 3. Among the genotypes studied, genotypes V_5 (4001X9848X4001), V_6 (Obantapa –10-3-2-1), and V_{15} (BR9943-DMR-SR) had superior seed quality, i.e., seed germination, seedling vigour 1, tetrazolium vigour, seedling fresh weight, seedling growth rate, seedling dry weight, seedling vigour index II and seed emergence. Unexpectedly, V_8 (Ku1414x9450) recorded low seed quality characters despite its highest 100 -seed weight. The poor germination recorded with variety V_8 (Ku1414x9450) could be possibly due to dormancy. Seed dormancy has been reported earlier in developing genotypes in rice. (Adebisi *et al.,* 2006).

The variance components (phenotypic, genotypic and error) for 11 seed and seedling vigour traits are given in Table 4. Lower values of error variance were observed when compared with values of genotypic variance for all traits evaluated. Higher genotypic variance values over error variance values for some traits were observed by Nayakar (1976) for niger (*Guizotia abyssinica (ass)*, Baye (2002) for *Vernonia galanensis* and Okelola (2005) for NERICA rice. The lower the error variance when compared with genotypic variance indicates that the larger proportion of variability is as a result of the genetic factor (genotype) not environmental factor (non-genetic factor). The result further revealed that the variability shown in the phenotypes for the traits was due to genetic factor rather than non-genetic basis (environmental factor). These variations, as a result of genotypic variance, indicate considerable scope of selection. Similar finding was observed by Berry *et al.* (1970) for *Vernonia anthemintica,* Gupta and Gadawat (1981) and Satapath *et al.* (1987) for linseed and Baye (2002) for *Vernonia galamensis*.

Table 4

Estimates of phenotypic (Vp), genotypic (Vg) and error (Ve) variances for 11 seed and seedling vigour traits over 15 Maize Inbreds

Characters	Phenotypic Variance [Vp]	Genotypic Variance [Vg]	Error Variance [Ve]
Seed Germination [%]	541.040	513.810	27.230
Seedling Emergence [%]	577.710	543.130	34.580
Root Length [cm]	5.530	2.570	2.960
Shoot Length [cm]	4.280	3.960	0.320
Seedling Vigour Index [I]	228467.110	189094.770	39372.340
Seedling Vigour Index [II]	17.240	16.580	0.660
100 Seed weight [g]	973.330	960.850	12.480
Tetrazolium vigour [%]	83.680	55.080	28.600
Seedling Dry Weight [g]	0.002	0.001	0.002
Seedling Fresh Weight [g]	0.047	0.033	0.0140
Seedling Growth Rate [g/day]	0.000	0.000	0.000

The PCV, GCV, mean, range, broad-sense heritability (h^{2}B) and genetic advance as a percentage of mean are shown in Table 5. PCV for seed germination, seed emergence, shoot length, seedling vigour index I and seedling vigour index II recorded the highest values of between 30.0 and 42.3 %, whereas tetrazolium vigour had the lowest, and other characters had values between 15.80 and 23.93 %. However, GCV followed the same trend as PCV except for seedling dry weight that recorded lowest GCV when compared with PCV. The Broad Sense heritability estimates for most characters were high except for some characters such as seedling growth rate, seedling dry weight and root length which recorded lower values. Genetic advance (GA) as percentage of mean was high for most characters except for seedling dry weight which had the lowest.

Table 5

Estimates of mean, range, phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV), heritability (H^{2}B) and genetic advance (GA) as percent of mean of eleven seed vigour traits over 15 of maize inbred

Characters	Mean	Range	PCV [%]	GCV [%]	H^{2}B [%]	GA [% of Mean]
Seed Germination [%]	77.41	40.00 — 96.00	30.05	29.28	94.97	58.78
Seedling Emergence [%]	61.13	30.00 — 100.00	39.92	38.12	94.01	76.16
Root Length [cm]	9.87	2.37 — 23.96	23.83	16.24	46.47	23.18
Shoot Length [cm]	6.89	3.53 — 9.67	30.03	28.88	92.52	57.81
Seedling Vigour Index I	1317.24	141.60 — 2400.84	36.29	33.01	82.77	61.87
Seedling Vigour Index II	9.83	0.432 — 6.048	42.30	41.42	96.17	84.44
100 Seed Weight	130.40	17.05 — 34.39	23.93	23.77	98.72	48.65
Tetrazolium vigour [%]	78.54	40.00 — 92.00	11.85	9.45	65.82	15.78
Seedling Dry Weight [g]	0.31	0.1791 — 0.8380	15.80	7.90	25.00	8.14
Seedling Fresh Weight [g]	1.095	0.729 — 2.828	19.80	16.99	70.21	29.06
Seedling Growth Rate [g × day^{-1}]	0.031	0.018 — 0.084	16.13	9.13	32.00	10.63

The phenotypic coefficient of variation (PCV) was generally higher than the genotypic coefficient of variation (GCV) for all characters except for some characters with same values. The variation of the 15 genotypes for seed and seedling vigour traits suggests that improvement through selection for some of these traits could be effective. However, improvement efficiency is related to magnitude of GCV, heritability and genetic advance. (Johnson, 1955). In this study, seed germination, seed emergence, shoot length, seedling vigour index I and seedling vigour index II with high values of GCV, heritability and GA indicated that improvement in these genotypes through direct selection for the above traits is possible.. Higher GCV indicates that significant improvement could be obtainable for such traits while the lower GCV for some traits revealed that they are less amenable to improvement through selection.

The result of principal component analysis of 11 seed and seedling vigour characters is shown in Table 6. The arithmetic sign of the coefficient is irrelevant, because a common rule of thumb for determining the significance of a trait coefficient is to treat coefficient greater than 0.30 as having a large enough effect to be considered important (|Okelola, 2005). Characters having less than 0.30 coefficient values were considered to be of no effect to the overall variation observed in the study. PC_1 accounted for 51.15 % of the variability and was dominated by seed emergence (0.371), root length (0.870), shoot length (0.340), seedling vigour index I (0.544), seedling vigour index II (-0.639), tetrazolium vigour (-0.655), seedling dry weight (0.938), seedling fresh weight (0.947) and seedling growth rate (0.938). PC_2 accounted for 26.458 % of the total variation and was related to seed germination (0.933), seed emergence (0.548), shoot length (0.694), seedling vigour index I (0.717), seedling vigour index II (0.677) and tetrazolium vigour (0.431).

Table 6

Results of Principal Component Analysis (PCA) of Eleven Seedling Vigour Traits Evaluated in Maize inbred lines

Characters	Principal Component	
	PC I	PC II
Seed Germination [%]	-0.034	**0.933**
Seedling Emergence [%]	**0.371**	**0.548**
Root Length [cm]	**0.870**	0.206
Shoot Length [cm]	**0.340**	**0.694**
Seedling Vigour Index I	**0.544**	**0.717**
Seedling Vigour Index II	**-0.639**	**0.677**
100 Seed Weight	**-0.908**	0.207
Tetrazolium Vigour [%]	**-0.655**	**0.431**
Seedling Dry Weight [g]	**0.938**	0.019
Seedling Fresh Weight [g]	**0.947**	-0.118
Seedling Growth Rate [g/day]	**0.938**	0.019
Variance [%]	51.147	26.458
Cumulative Variance [%]	51.147	77.604
Total	5.626	2.910

Bolded: Significant Contribution

The principal component analysis showed that seed emergence, root length, shoot length, seedling vigour index I, seedling vigour index II, seedling fresh and dry weight, seedling growth rate, 100 seed weight and tetrazolium vigour as revealed in PCA I and II contributed greatly to the variation among 15 maize inbred lines. These characters could be used as dependable selection criteria because of great genetic contribution to the total variation. This observation is in line with Clifford and Stephenson (1975), Kehinde *et al.* (2005), Okelola (2005), Adebisi *et al.,* (2006) who reported that the first principal component was the most paramount in showing the variation patterns among varieties and the characters highly associated with these should be used in differentiating varieties.

Table 7

Correlation analysis showing the relationship among seed vigour characters in maize inbred lines (N= 90)

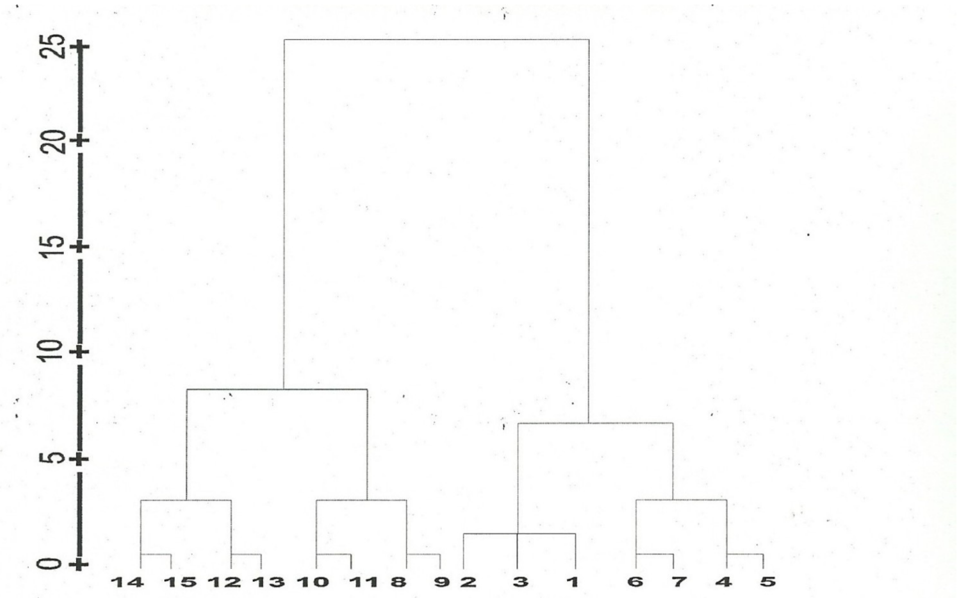
Characters	1	2	3	4	5	6	7	8	9	10
1 — Seed Germination [%]	0.54^{**}	0.11^{ns}	0.55^{**}	0.61^{**}	0.66^{**}	0.18^{ns}	0.32^{**}	-0.03^{ns}	-0.14^{ns}	-0.03^{ns}
2 — Seedling Emergence [%]		0.30^{**}	0.28^{**}	0.45^{**}	0.11^{ns}	-0.29^{**}	-0.05^{ns}	0.33^{**}	0.31^{**}	0.33^{**}
3 — Root Length [cm]			0.38^{**}	0.73^{**}	-0.44^{**}	-0.71^{**}	-0.37^{**}	0.80^{**}	0.76^{**}	0.80^{**}
4 — Shoot Length [cm]				0.68^{**}	0.21^{*}	-0.20^{ns}	0.02^{ns}	0.28^{**}	0.24^{*}	0.28^{**}
5 — Seedling Vigour Index I					0.07^{ns}	-0.33^{**}	-0.06^{ns}	0.46^{**}	0.37^{**}	0.46^{**}
6 — Seedling Vigour Index II						0.79^{**}	0.67^{**}	-0.50^{**}	-0.64^{**}	-0.50^{**}
7 — 100 Seed Weight [g]							0.70^{**}	-0.77^{**}	-0.86^{**}	-0.77^{**}
8 — Tetrazolium Vigour [%]								-0.53^{**}	-0.64^{**}	-0.53^{**}
9 — Seedling Dry Weight [g]									0.91^{**}	1.00^{**}
10 — Seedling Fresh Weight [g]										0.91^{**}

** Correlation is significant at 1% level of probability; * Correlation is significant at 5% level of probability; ns — not significant; numbers in the first row refer to characters

Table 7 shows the correlation coefficients among seed vigour and seedling emergence characters (N = 90). There were positive and significant correlations between seed germination and seed emergence, shoot length, seedling vigour index I, seedling vigour index II and tetrazolium vigour. There were also positive and significant correlations between seed emergence and all the seed quality characters except for 100-seed weight (-0.29**) that was negatively correlated. All the characters were positively and significantly correlated with root length except for seedling vigour index II, 100-seed weight and tetrazolium vigour test that were negatively correlated. Shoot length had positive and significant correlations with all other characters except for 100-seed weight and tetrazolium vigour. Similarly, seedling vigour index I had positive and significant correlation with other traits except for 100-seed weight (-0.33**): the latter was a significant and negative correlation. Seedling vigour index II was positively and significantly correlated with other traits except for seedling dry weight, seedling growth rate and seedling fresh weight, which had significant and negative correlations. The 100-seed weight had positive and significant correlations with tetrazolium vigour, whereas other traits had significant and negative correlations. Tetrazolium vigour had a negative and significant correlation with seedling fresh weight (r = 0.91**) and seedling growth rate (r = 1.00**), whereas seedling fresh weight was positively and significantly correlated with seedling growth rate (r = 0.91**).

Result of the correlation analysis futher showed that characters were differently associated with each other. Adebisi (2008) pointed out that strong positive correlation suggests that selection for one trait could be used to indirectly select for another character but this can cause difficulties during selection if the association is between desirable and undesirable traits. The positive and significant correlations recorded between seed germination and all other characters except 100-seed weight, root length, seedling dry weight, seedling fresh weight and seedling growth rate implies that seeds with high germination will lead to increase in characters that recorded positive correlations with seed germination while seed with high germination will lead to decrease in seedling dry weight, root length, seedling fresh weight and seedling growth rate. Similarly, seed germination, shoot length, seedling vigour index I, 100-seed weight, seedling fresh weight and seedling growth rate had good correlations with seed emergence; hence they are good predictors of seed emergence in maize inbred lines. In general, the seed germination characters have been shown to be an excellent predictor of field emergence and seedling vigour (Egli *et al.,* 1979. Adebisi *et al.,* 2006 and Adebisi, 2008) in some crop species. Seedling growth rate was found to be function of seed emergence, root length, shoot length, seedling vigour index I and II, 100-seed weight, tetrazolium vigour, seedling dry weight and seedling fresh weight because all these characters significantly correlated with seedling growth rate.

The dendrogram (Fig. 1), constructed using seed germination data, represents the clustering pattern of the 15 maize inbred genotypes. Cluster analysis is a method often extended to genotype's groupings to cluster entries that show similarity in one or more characters, thus guide in the choice of genotypes for crop improvement(Akintobi *et al.,* 2002, Adebisi *et al.,* 2010). In this study, the cluster analysis classified the 15 genotypes into two distinct clusters with seven (46.67%) genotypes clustered in group I and eight (53.33%) grouped in cluster II. Classification of the maize inbred lines into separate distinct clusters indicates that hybridization of maize inbred lines across clusters could lead to increase in heterotic effects in the cross progenies.



V_1[(4001 × 9848) × 4001]–1-1-2-B-B-B-1-B-B-B-B-B-B-B-B
V_2 (9071 × 4058) –8-2-1-1-B-B-B
V_3 (MP420 × 4001 × mp420) –3-1-2-1-B-B-B-B-B-B-B
V_4 (1368 × 1824) –4-2-2-1-2-B-B-B
V_5 (4001 × 9848 × 4001)-29-1-4-B-1-B-B-B-B-B-B-B-B
V_6 Obantapa –10-3-2-1-B-B-B-B-B-B-B-B-B-B-B-B-B
V_7 Obantapa –23-3-1-B-B-B-B-B-B-B-B-B-B-B-B-B
V_8 (Ku1414 × 9450)-24-2-1-B-B-B-1-B-B-B-B-B-B-B-B
V_9 –AG Seeds-361-1-1-1-B-B-B-B-B-B-B-B-B-B-B-B
V_{10} 4001
V_{11} TZB-SR
V_{12} (9071 × 5057)-3-2-1-1-B-B-B
V_{13} Pioneer Seeds -26-2-1-B-B-B-B-B-B-B-B-B-B
V_{14} (1368 × 9091)-8-1-3-1-2-B-B-B
V_{15} (BR9943-DMR-SR)

Fig. 1. Dendrogram shows the clustering pattern of the 15 maize inbred lines using seed germination data

In conclusion, significant variability was found among the 15 maize inbred lines for all the laboratory and field seed quality characters examined. Genotype V_5 (4001X9848X4001) had superior seed quality traits compared to other genotypes. Seedling emergence, shoot length, seedling vigour index I, seedling vigour index II and tetrazolium vigour are effective characters which can be considered for good seed and seedling vigour traits in maize inbred lines investigated..

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