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Seed Vigour of Quality Protein Maize Varieties Belonging to Different Maturity Groups

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Authors' contributions

This work was carried out by the author OJO under the supervision of the author ASA. It was a PhD work of the author OJO. Authors OJO and ASA designed the study. Author OJO collected data, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript under the supervision of author ASA. Both authors read and approved the final manuscript.

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ABSTRACT

Laboratory tests were carried out to investigate inherent quality differences among stored seeds of early, intermediate and late-maturing quality protein maize using completely randomized design (CRD) with three replications at the Seed Testing Laboratory of the Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria for two consecutive years (2014 and 2015). From the results, germination and accelerated ageing germination traits were affected by the storage period. Similarly, the seed performance on germination, accelerated ageing and the conductivity test were seen to be better in early-maturing than in other maturing maize genotypes. The speed of germination measured as the germination index was low; ranging from 3.24-3.68 days after sowing (DAS) irrespective of the maturity group. Seedling traits measured after physiological quality tests were equally affected by the storage period and the maturity group. All the seedling traits measured were better in the early-maturing genotypes. Seed quality measured by laboratory quality assessments showed that genotypes in the early-maturing group are of high quality. Seeds of early-maturing genotypes

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retained significantly higher physical and physiological quality parameters and appear to have inherent potential to withstand effects of deterioration due to their slower rate of quality decline.

Keywords: Quality protein; seed quality; germination index; storage; maturity group.

1. INTRODUCTION

Maize is a major cereal crop for human nutrition worldwide. Several million people, particularly in the developing countries**,** derive their protein and calories requirements from maize. In many developing countries of Latin America, Africa and Asia, maize is the major staple food and often the only source of protein because animal protein is scarce and expensive and consequently, unavailable to a vast sector of the population [1]. One of the main nutritional limitations of normal maize grain is its poor nutritional profile because of a deficiency in essential amino acid**s** such as lysine, tryptophan and methionine [2]. Normal maize has 10% protein which is of poor nutritional quality due to limiting concentrations of essential amino acids (lysine and tryptophan) which the human body cannot synthesise and has to be supplemented [3,4,5]. Therefore, adoption and cultivation of Quality Protein Maize (QPM) with high concentration of lysine and tryptophan could drastically reduce malnutrition, diseases and death among low income maize consumers in the developing countries, including Nigeria [6, 7].

Maize production in the southern guinea savannah (SGS) of Nigeria is constrained by several factors including drought, low soil nutrient status, susceptibility to pests and diseases, poor adaptation to the agro-ecologies [8,9] and limited availability of high quality seeds of known and traceable origin. Seed is a fundamental input; the most important and comparatively the least expensive of all external inputs in crop production. The quality of seeds, (physiological seed properties) which determines the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions [10] is an essential determinant of crop productivity. The use of seeds with high physiological potential is indispensable for success in agricultural production, and makes a significant contribution to rapid stand establishment and the initial development of vigorous seedlings in the field [11]. Therefore, quality assurance during production, harvesting and post-harvest handling of harvested seed mass is an important consideration both in research and commercial seed production. Maize breeders have evaluated exotic germplasm for desirable agronomic and quality traits [12]. However, seed quality is usually not one of the selection criteria. Seed scientists are concerned that breeders do not evaluate seed quality characters in their breeding programmes [13]. It is essential for producers that the improvement of the nutritional value of maize is not done at the expense of seed quality. Seed physiological quality is one of the major important factors affecting early performance and productivity of most agricultural crops. Generally there is inadequate seed quality assurance infrastructure for seed testing in developing countries. Quality assurance is required to increase crop productivity and enhance food security in these countries [14]. Thus there exist ample opportunities in Nigeria to enhance crop productivity and food security through appropriate seed technologies. One of the main problems often observed in the field is poor seedling establishment which is influenced by seed quality, climatic conditions and field management practices [15,16]. Seed vigour is the sum of those properties of the seed that determine the activity and performance of seed lots of acceptable germination in a wide range of environments [17]. Low vigour seed lots contribute to the development of uneven seedlings in plant stands and therefore reduce final yield. It has been widely reported that the longer the period of seed storage, the lower the seed quality and consequently the yield [18]. Seed quality is a collective term for the state of a seed lot including genetic homogeneity, physical appearance, viability, vigour, and uniformity [19]. Other characteristics such as specific chemical composition or resistance to certain insect pests and diseases also contribute to the quality of seed. In general, the quality of seed is measured in many ways. These include genetic and physical purity, germination, vigour, uniformity in size, freedom from seed-borne diseases, and other factors like heat and or mechanical damage [20] as well as pre-harvest sprouting [21,22] affecting seed performance in the field. Therefore, the study aimed to investigate inherent physiological quality differences among

seeds of early, intermediate and late-maturing maize genotypes.

2. MATERIALS AND METHODS

2.1 Planting Materials

The experimental biological materials comprised 12 Quality Protein Maize (QPM) genotypes belonging to three different maturity groups namely early, intermediate and late-maturity group which were stored for a period of 15 months. Seeds of nine of the QPM genotypes were developed at the Maize Improvement Programme of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The other three genotypes were obtained from the Cereals Improvement Programme of the Institute of Agricultural Research and Training (IAR&T), Moor Plantation, Ibadan, where they were developed. The seeds of the genotypes were multiplied during the late season of 2013. Harvesting and processing were done in December 2013. After the preliminary evaluation of seed quality, the envelopes containing the genotypes were put inside polyethene bags for storage in the cold room of the IAR& T during the period of the study.

2.2 Seed Quality Assessment

The quality of seeds of 12 QPM genotypes (4 early, 4 intermediate and 4 late-maturing genotypes) was assessed with the following tests in the Seed Testing Laboratory of the Institute. The list of the maize genotypes used is presented in Table 1.

2.2.1 Standard germination

Standard germination test was carried out in three replications of 50 seeds per replicate. Plastic germination bowls were filled with moistened sharp sand and seeds were evenly spaced on the sand and thereafter thinly covered with moistened sand and lightly pressed for a good seed-substratum contact. The bowls were covered with nylon sheets to conserve moisture and kept at room temperature. Germination counts were made daily from the 4^{th} to 7^{th} day after planting. On the 7^{th} day, seedling analysis was carried out and the numbers of normal and abnormal seedlings were recorded. Germination was calculated as the percentage of seeds producing normal seedlings [23]. After seedling analysis, five seedlings were selected at random for the determination of seedlings traits such as number of roots, root length, shoot length ,root dry weight, shoot dry weight, seedling length and seedling vigour index.

Seedling Vigour Index = (Seedling length x Germination %) / 1000

2.2.2 Electrolyte Leakage (EL)

Fifty intact and clean seeds in three replicates were counted, weighed, and placed in a glass flask containing 100 ml of distilled water. The flasks were covered with aluminum foil to prevent contamination and the flasks were gently shaken

Table 1. List of quality protein maize genotypes used for the study

S/N	Pedigree	Code	Maturity group	Source
1	EVDT-W99STRQPMC0	EVDT-W99	Early	IITA
2	DMR-ESR-WQPM	DMR-ESR-W	Early	IITA
3	TZE-YPOPDTSTRQPMC1	TZE-YPOPDT	Early	IITA
4	POOL-18SR	POOL-18SR	Early	IITA
5	ART/98/SW5-OB	ART/98/SW5-OB	Intermediate	IAR&T
6	ART/98/SW6-OB	ART/98/SW6-OB	Intermediate	IAR&T
7	ART/ILE-1-OB	ART/ILE-1-OB	Intermediate	IAR&T
8	POP66-SR/ACR.91SUWAN1-8RC1/ACR.91SUWAN1-SRC1	POP66-SR/ACR.91	Intermediate	IITA
9	SYNLDFO/OBATANPA/IWDC2SYN*2	SYNLDFO/OBANTAPA	Late	IITA
10	SYNLDFO/OBATANPA/TZLCOMP.4C3*2	SYNLDFO/OBAT	Late	IITA
11	SYNLDFO/OBATANPA/TZLCOMP.3C3*2	SYNLDFO/OBAT/TZL	Late	IITA
12	OBATANPA/TZLCOMP./SYN-W-1/TZLCOMP./SYN-W-/F2	OBATANPA/TZLCOMP.	Late	IITA

IITA- International Institute of Tropical Agriculture, Ibadan IAR&T- Institute of Agricultural Research and Training, Moor Plantation, Apata, Ibadan

intermittently. Electrical conductivity measurements of the solutions (as an indicator of electrolyte leakage) were taken after 24 hours at 25°C reference temperature using Mettler Toledo MC126 conductivity meter. All measurements were expressed as $\mu Scm^{-1}g^{-1}$ and the values were calculated as suggested by [24]:

> Electrolyte leakage ($\mu Scm^{-1}g^{-1}$) = (Electrical conductivity (µS) of each flask-cond. of water) / Initial weight of seed sample

2.2.3 Accelerated ageing

Ageing of seeds was determined by weighing 50 seeds from each subsample in three replicates. Thereafter, the seeds were placed on a wire mesh suspended over water inside accelerated ageing boxes and then placed in an ageing chamber for 72 hours at a temperature of 43°C. The seeds were re-weighed after ageing to determine the amount of moisture gained during the ageing process. After the ageing period, the seeds were subjected to standard germination test as described above and the germination count on the 5^{th} and 7^{th} days' after planting. The results were expressed in percentage as done for standard germination. Accelerated ageing index (AAI) was similarly calculated from the accelerated ageing germination data.

2.3 Statistical Analysis

Data collected were subjected to analysis of variance ANOVA separately for each maturity group and combined across maturity groups and the two years using general linear model procedures in statistical analysis system (SAS) version 9.2. [25], to compute mean squares for each character. Mean separation was done using Duncan Multiple Range Test (DMRT). Regression analysis was run to generate b-value (slope). Descriptive statistics was also carried out to compute mean, standard deviation and range.

3. RESULTS

Mean values for physiological quality of maize genotypes of different maturity groups presented in Table 2. All the traits were significantly affected by duration of storage when averaged over maturity groups. Hundred seed weight reduced by 5.46 % 15 months after storage. At the initial stage of the trial, average germination was 82.78 % $\mu Scm^{-1}g^{-1}$ this was significantly reduced by about 13 % 15 months after storage. Germination index (GI) and accelerated aging germination index (AAGI) were delayed by I day as compared to initial and 9 months after storage. Accelerated aging also reduced significantly by 44.9% from 66.25% to 36.49% at initial and 15 months after storage, respectively. Electrolyte leakage recorded 77.5% increase from 14.03 $\mu Scm^{-1}g^{-1}$ to 24.90 $\mu Scm^{-1}g^{-1}$ at initial and 15 month in storage. Early- maturing genotypes showed highest mean values for hundred seed weight (HSW), standard germination (SG) and accelerated aging germination (AAG) but with significant and lower mean values for standard germination index (SGI), accelerated ageing germination index (AAGI) and Electrolyte leakage (EL). Number of roots (RN) was not affected until after 15 months in storage (Table 3). Root length (RLT), Root dry weight (RDW) and Shoot dry weight (SDW) progressively reduced and the difference was significant by 15 months in storage. There was a general trend of decrease in both seedling length (SDL) and seedling vigour index (SVI) during storage period with values of 20.43 cm and 1.59 after 15 months in storage from 25.81 cm and 2.17 respectively at the beginning of storage. All the seedling traits measured were highest in the early-maturing genotypes followed by the late-maturing genotypes and intermediate genotypes.

The genotypic mean values for all traits, evaluated in each maturity group are presented in Table 4. Laboratory SG (%) ranged from 41.11% to 95.89%. The lowest SG (%) of less than 50 was recorded in two of the intermediate genotypes (41.11% and 44.67% for ILE-1-OB and POP66-SR/ACR 91, respectively). Irrespective of the maturity group, the SGI was low ranging from 3.24-3.68 days after sowing (DAS). Average AAG ranged from 36.11 in ART/98/SW5 (intermediate) to 83.11 in TZE-POPDT (early) respectively. Maximal level of performance in AAG was reached in 2 out of the 4 genotypes in early maturing group. The difference in AAGI among the 12 maize genotypes was small. Electrolyte leakage values ranged from 7.77 $\mu Scm^{-1}g^{-1}$ in EVDT-W99 (early) to 62.42 $\mu Scm^{-1}g^{-1}$ in ILE-1-OB (intermediate). All the measured seedling traits after physiological quality tests were highest in the early-maturing genotypes (Table 5). Number of root ranged from 4.84 in EVDT-W99 to 3.16 in ILE-1-OB. SVI also ranged from 2.53 in TZE-YPOPDT to 1.50 in ART/98/SW 5-OB.

Table 2. Mean values of physiological quality of twelve maize genotypes belonging to three maturity groups, tested under varied storage durations

	Hundred seed weight (g)	Germination percentage	Germination index (days)	Accelerated aging germination percentage	Accelerated aging germination index (days)	Electrolyte leakage ($\mu Scm^{-1}g^{-1}$)
Duration of storage						
Initial	25.80a	82.78a	3.20a	66.25a	4.21a	14.03b
9 Months	25.76a	70.19b	3.11a	53.24b	4.16a	25.48a
15 Months	24.39b	70.19b	4.11b	36.49c	5.15b	24.90a
b-value ± SE	-0.08 ±0.14	-0.88±0.06	0.88±0.38	0.06±0.04	-1.94±0.37	0.16±0.04
Maturity group						
Early	26.95a	85.92a	3.34a	68.56a	4.33a	11.14c
Inter	23.20c	54.19b	3.57b	37.85c	4.84b	39.23a
Late	25.80b	83.00a	3.51b	49.58b	4.35a	14.05b

Means with the same letter in each column are not significantly different at P = 0.05 using Duncan's multiple range test

Table 3. Mean values of seedling traits of twelve maize genotypes of three maturity groups tested under different durations of storage

	Number of roots	Root length(cm)	Shoot length(cm)	Root dry weight(g)	Shoot dry weight(g)	Seedling length(cm)	Seedling vigour index
Storage duration							
Begin	4.72a	16.05a	9.76a	0.044a	0.055a	25.81a	2.17a
9 Months	4.50a	15.61a	8.60b	0.043a	0.056a	24.21b	1.71b
15 Months	2.82b	11.65b	8.78b	0.031b	0.047b	20.43c	1.59b
b-value ±SE	-0.12 ±0.06	-0.27 ±0.16	-0.07 ±0.04	-0.00 ±0.00	-0.00 ±0.00	-0.34 ±0.12	-0.04 ±0.01
Maturity group							
Early	4.58a	15.41a	9.87a	0.042a	0.060a	25.27a	2.19a
Inter	3.52c	12.67b	8.39c	0.035b	0.047c	21.05b	1.16c
Late	3.96b	15.24a	8.89b	0.041a	0.052b	24.13a	2.05a

Means with the same letter in each column are not significantly different at P = 0.05 using Duncan's multiple range test

Table 4. Mean values of physiological quality of the twelve maize genotypes belonging to three maturity groups across storage durations

Variety	HSW (g)	G %	GI (days)	AAG %	AAGI (days)	EL ($\mu Scm^{-1}g^{-1}$)
Early						
EVDT-W99	25.94b	88.67a	3.24a	81.89a	4.20a	7.77a
DMR-ESR-W	25.69b	80.44b	3.41b	47.22c	4.52b	12.19b
TZE-YPOPDT	27.89a	95.89a	3.44b	83.11a	4.28b	12.97b
POOL-18SR	28.28a	78.89b	3.26a	62.00b	4.31b	11.69b
Mean	26.95	85.92	3.34	68.55	4.32	11.14
Intermediate						
ART/98/SW5-OB	22.87b	64.74b	3.24a	37.85ab	4.85b	39.23a
POP66-SR/ACR 91	23.79a	44.67c	3.82c	36.11b	4.89b	29.41a
ILE-1-OB	22.69b	41.11c	3.67ab	39.11a	4.91b	62..42b
ART/98/SW6-OB	23.46a	66.22a	3.56b	38.33ab	4.74a	25.85a
Mean	23.20	54.19	3.57	37.85	4.84	39.23
Late						
SYNLDFO/OBATANPA	24.20c	88.22a	3.42a	64.44a	4.37a	14.42ab
SYNLDFO/OBAT	26.63b	68.00b	3.68b	48.33b	4.75a	16.92b
SYNLDFO/OBAT/TZL	28.07a	90.44a	3.51a	40.44b	3.96a	10.82a
OBATANPA/TZLCOMP	24.28c	85.33a	3.46a	45.11b	4.30a	14.02ab
Mean	25.80	83.00	3.51	49.58	4.35	14.05

Means with the same letter in each column are not significantly different at P =0.05 using Duncan's multiple range test. HSW=Hundred Seed Weight; G= Germination percentage; GI= Germination Index; AAG=Accelerated Ageing Germination; AAGI=Accelerated Ageing Germination Index; Electrolyte Leakage ($\mu Scm^{-1}g^{-1}$)

Table 5. Mean values of seedling traits after physiological quality tests of twelve tropical maize genotypes belonging to three maturity groups across storage durations

Variety	RN	RLT(cm)	SL(cm)	RDW(g)	SDW(g)	SDL(cm)	SVI
Early							
EVDT-W99	4.84a	14.10a	10.40a	0.04a	0.07a	24.49b	2.20b
DMR-ESR-W	4.53ab	15.66a	8.85b	0.03a	0.05b	24.50b	1.98b
TZE-YPOPDT	4.16b	16.66a	9.70ab	0.05a	0.06a	26.36a	2.53a
POOL-18SR	4.81a	15.23a	10.51a	0.05a	0.06a	25.74a	2.03b
Mean	4.58	15.41	9.87	0.04	0.06	25.27	2.19

Variety	RN	RLT(cm)	SL(cm)	RDW(g)	SDW(g)	SDL(cm)	SVI
Intermediate							
ART/98/SW5-OB	3.40bc	12.52a	7.55c	0.03a	0.04b	20.07b	1.50a
POP66-SR/ACR 91	3.57b	11.66a	9.22a	0.03a	0.05a	20.88b	0.99b
ILE-1-OB	3.16c	11.72a	7.87c	0.04a	0.04b	19.59c	0.91b
ART/98/SW6-OB	3.94a	14.78a	8.91b	0.04a	0.05a	23.69ab	1.57a
Mean	3.52	12.67	8.39	0.03	0.05	21.05	1.16
Late							
SYNLDFO/OBANTAPA	3.79b	15.21a	9.62a	0.04a	0.05ab	24.83a	2.21a
SYNLDFO/OBAT	4.20a	14.42a	8.87b	0.04a	0.05ab	23.08a	1.61b
SYNLDFO/OBAT/TZL	4.16a	16.07a	8.91b	0.04a	0.06a	24.97a	2.28a
OBANTAPA/TZLCOMP	3.69b	15.26a	8.37b	0.04a	0.04b	23.64a	2.03a
Mean	3.96	15.24	8.89	0.04	0.05	24.13	2.05

Means with the same letter in each column are not significantly different at P = 0.05 using Duncan's multiple range test. RN=Number of roots; RLT=Root Length; SL=Shoot Length; RDW=Root Dry Weight; SDW=Shoot Dry Weight; SDL=Seedling Length; SVI=Seedling Vigour Index

4. DISCUSSION

Successful crop production requires the use of high quality seeds to achieve good crop establishment count and high crop yield. High quality seeds are demanded by the end users to ensure maximum seedling emergence and stand establishment in the field [26]. High quality seeds can perform well in the field, ensuring optimum stand establishment and satisfactory grain yield under a wide range of environmental conditions [27]. The most obvious component of seed quality is germination capacity and germination tests are used worldwide to determine the maximum germination potential of a seed lot under optimum conditions. Therefore germination capacity should be considered a priority in seed production. The significant effect of storage period across maturity groups on germination indicates that seed lots deteriorated progressively as storage period increased. Generally, germination percentage decreased from 0 month to 15 month of duration at the rate of 0.88. Seed deterioration was still evident in the seed lots after 15 months in storage due to a day' delay in the speed of germination. This could be ascribed to loss of vigour due to ageing during storage. This implies that no matter how perfect the storage facilities and conditions are, the potential of seed lot deteriorates with storage period. This agreed with the works of [28] who reported a marked reduction in vigour due to seed ageing and [29] that reported reduced viability, rate and capacity of germination also due to seed ageing. Lower viability recorded in the intermediate-maturing genotype is in agreement with the findings of [30] who reported that varieties differed significantly in germination percentage.

The vigour of the early materials was better than the other maturing groups due to faster emergence as measured by the germination index. Seed weight as an index of seed quality was high in the early-maturing genotype and this contributed greatly to the quality of early maturing genotypes. Large seeds of the early-maturing genotypes enhanced the germination percentage, the production of more vigorous seedlings, higher, seedling length, dry weight and seedling vigour index. This agreed with the works of [31,32] they reported that seed weight and seed nutrient content affect plant growth at seedling stage. From this study, potential performances such as storage quality and physiological quality were assessed using accelerated ageing (AAG) and electrolyte leakage (EL). The AAG made it possible to determine if certain seed lots had a lesser or greater germination capacity, and to determine the storage potential of seed lots [33]. Seed vigour as assessed by AAG test showed a declining trend in viability after ageing and all other traits were significantly affected by seed ageing as indicated by the variation in values over storage period. Reduced seed germination following seed ageing treatment might have resulted from the increased solute leakage following imbibition which is usually accompanied with inevitable exist of some necessary materials for germination and normal seedling growth. This result is in agreement with those of [34,35,36]. The authors worked with different crops and reported that electrical conductivity and germination rate tests are suitable for evaluation of seed vigor in both laboratory and field experiments. Low conductivity value at the beginning of the trial showed that all the seed lots used were of high vigour.

5. CONCLUSION

Based on the above discussion it is concluded that: Significant mean squares for maturity groups and storage durations for all the measured traits in the laboratory seed quality assessment indicated that the genotypes used are of different physiological status and storage potentials. Seeds of early, intermediate and late-maturing genotypes exhibited inherent differences in physical and physiological seed quality. Seeds of early genotypes had significantly higher physical and physiological quality parameters. They appeared to have inherent potential to withstand deterioration due to their slower rate of deterioration.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Vasal SK. Quality protein maize story. Proceedings of the Workshop on Improving Human Nutrition through Agriculture: The Role of International Agricultural Research, October 5-7, 1999, Philippines, 2002;1-16.
2. Huang S, Frizzi A, Florida CA, Kruger DE, Luethy MH. High lysine and high tryptophan transgenic maize resulting from the reduction of both 19- and 22-kD α-

zeins. Plant Molecular Biology. 2006;61: 525-535.

3. Krivanek AF, Hugo D G, Nilupa SG, Alpha OD, Dennis F. Breeding and disseminating quality protein maize (QPM) for Africa. African Journal of Biotechnology. 2007; 6(4):312-324.
4. Mbuya K, Nkongolo KK, Kalonji-Mbuyi A, Kizungu R. Participatory selection and characterization of quality protein maize (QPM) varieties in savanna agro-ecological region of DR-Congo. Journal of Plant Breeding and Crop Science. 2010;2(11): 325-332.
5. Mbuya K. Nkongolo KK, Kalonji-Mbuyi A. Nutrition analysis of quality protein maize selected for agronomic characteristics in a breeding program. International Journal of Plant Breeding and Genetics. 2011;2(11): 325-332.
6. Olakojo SA, Omueti O, Ajomale K, Ogunbodede BA. Development of quality protein maize: Biochemical and agronomic evaluation. Tropical and Subtropical Agroecosystem. 2007;7:97-104.
7. Upadhyay S, Gurung DB, Paudel DC, Koirala KB, Sah SN, Prasad RC, Pokhrel BB, Dhakal R. Evaluation of quality protein maize (QPM) genotypes under rainfed mid hill environments of Nepal. Nepal Journal of Science and Technology. 2009;10:9-14.
8. Olaoye G, Bello OB, Olayiwola LS, Abubakar AY. Induced moisture deficit grain yield loss in drought tolerant maize germplasm accessions. Proceeding of the 29th Annual Conference of the Genetics Society of Nigeria. 11th-14th October. University of Agriculture, Abeokuta, Nigeria. 2004;176-182.
9. Olaoye G, Bello OB, Ajani AK, Ademuwagun TK. Changes in quantitative and qualitative characters in the segregating F2 population of sweet corn (*Zea mays* L.) crosses. Proceeding of the 30th Annual Conference of the Genetics Society of Nigeria. 5-6 September. University of Nigeria, Nsukka, Nigeria. 2005;74-84.
10. ISTA. International rules for seed testing. Handbook of vigor test methods. 3rd. Ed ISTA, Zurich. Switzerland; 2007.
11. Marcos-Filho J. Seed physiology of cultivated plants. ABRATES, Londrina, PR, Brazil; 2016.
12. Salhuana W, Pollack LM, Ferrer M, Paratori O, Vivor G. Breeding potential of maize accessions from Argentina, Chile, USA and Uruguay. Crop Science.1998;38: 866-872.
13. Burris JS. Physiology of seed development and deterioration in genetic improvement of seed quality. CSSA Spec. Publ. 36 CSSA. Madison, WI; 2000.
14. World Seed Congress Declarations. Available:http://www.seedtest.org/upload/cms/user/DECLERATION FROM THE SECOND WORLD SEED CONFERENCE. WEBI.Pdf
Retrived: 10th March, 2010].2009
15. Zhu S, Hong D, Yao J, Zhang X, Luo T. Improving germination, seedling establishment and biochemical characters of aged hybrid rice seed by priming with KNO_3 + PVA. African Journal of Agricultural Research. 2010;5:78-83.
16. Delouche JC. Seed quality and performance Seed news: The international seed magazine; 2004.
Available:http:/www.seednews.inf.br/ingles/archives.shtml
(Retrieved online March 13, 2010)
17. ISTA. International rules for seed testing. Basserdorf, Switzerlands International Seed Testing Association; 2015.
18. Ghassemi-Golezani K, Bakhshy J, Raey Y, Hosseinzadeh-Mahootchy A. Seed vigor and field performance of winter oilseed rape (*Brassica napu*s L.) cultivars. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 2010a;38:146-150.
19. Maguire JD. Seed quality and germination *in* A.A. Khan (ed.). The physiology and biochemistry of seed dormancy and germination. Amsterdam: North Holland Publishing Company; 1977.
20. Shah FS, Watson CE, Meredith ND, Bohn PA, Martin B. Effect of bean ladder usage on mechanical damage during soybean seed conditioning. Seed Technology. 2001;23:92-97.
21. Olasoji JO, Aluko AO, Adeniyan ON, Olanipekun SO, Olosunde AA, Okoh JO. Effect of time of harvest on physiological maturity and kenaf (*Hibiscus canabinus*) seed quality. African Journal of Plant Science. 2012;6(10):282-289.
22. Rodriguez MV, Barrero JM, Corbineau F, Gubler F, Bened-Arnold RL. Dormancy in cereals (not too much, not so little): about the mechanism behind this trait. Seed Science Research. 2015;25:99-119.
23. ISTA. International Rules for Seed Testing. Seed Science and Technology. 1993; 21(Suppl.)

24. Hampton JG, TeKrony DM. Handbook of seed testing vigor test methods. Zurich, International Seed Testing Association; 1995.
25. SAS Institute. SAS/STAT user's guide, Version 8, SAS Inst., Inc., Carg; 2002.
26. TeKrony DM. REVIEW: Precision is an essential component of seed vigor testing. Seed Science and Technology. 2003;31: 435-447.
27. Ghassemi-Golezani K, Khomari S, Dalil B, Hosseinzadeh-Mahootchy A, Chadordooz-Jeddi A. Effects of seed aging on field performance of winter oil-seed rape. Journal of Food, Agriculture and Environment. 2010b;8:175-178.
28. Gupta A, Aneja KR. Seed deterioration in soybean varieties during storage-physiological attributes. Seed Research. 2004;32:26-32.
29. Arefi HM, Abdi N. Study of variation and seed deterioration of *Festuca ovina* germplasm in natural resources genebank. Iranian Journal of Rangelands and Forests Plant Breeding and Genetic Resources. 2003;11:105-125.
30. Mahesha CR, Channaveeraswami AS, Kurdikeri MB, Shekhargouda M, Merwade MN. Storability of sunflower seeds harvested at different maturity dates. Seed Research. 2001;29:98-102.
31. Vandamme C, Pypers, P, Smolders E, Merckx R. Seed weight affects shoot and root growth among and within soybean genotypes beyond the seedling stage. Implications for low P tolerance screening. Plant Soil. 2016;101:65-78.
32. Huang M. Morphological and physiological traits of seeds and seedlings in two rice cultivars with contrasting early vigour. Plant Production Science. 2017;20:95-101.
33. Munamava MR, Goggi AS, Pollak L. Seed quality of maize inbred lines with different composition and genetic backgrounds. Crop Science. 2004;44: 542–548.
34. Rozrokh M, Ghassemi-Golezani K, Javanshi A. Relation between seed vigour and field performance in chickpea (*Cicer arietinum* L.). Tehran Journal of Agriculture Research Seed and Plant Improvement Institute. 2002;18(2):156-162.
35. Thornton JM, Powell AA. Prolonged aerated hydration for the improvement of seed quality in *Brassica oleracea* L. Annals of Applied Biology.1995;127:183-189.
36. Verma SS, Verma U, Tomer RPS. Studies on seed quality parameters in deteriorating seeds in Brassica (*Brassica campestris*). Seed Science and Technology. 2003;31: 389-396.

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